ACHIEVING UNIVERSAL ACCESS IN THE KEDCO SERVICE AREA

WORLD BANK GROUP

ESMAP
Energy Sector Management Assistance Program

Africa Renewable Energy and Access Program (AFREA)

SUSTAINABLE ENERGY FOR ALL

Preface

This Volume was produced under the Nigeria Electrification Access Program Development (NEAPD) Technical Assistance project for the Kano Electricity Distribution Company (KEDCO), which provides electricity services to the States of Kano, Katsina and Jigawa in North West Nigeria. The Volume is combined by two reports: a GIS-based Least-Cost Plan and a related Investment Prospectus. Together, they present a technically sound electrification and investment plan for the achievement of universal access to electricity services in the Kano service area by 2030. Both the Geospatial Plan and the Investment Prospectus were produced in close collaboration with KEDCO, and the NEAPD project also strengthened the utility's capacity through training for the geospatial mapping of the electricity infrastructure and for distribution planning with GIS tools.

The Least-Cost Plan provides a geospatial and quantitative frame for the design and detailing of a well-coordinated and harmonized implementation program for grid and off-grid electrification over a fifteen-year timeframe (2015–2030). Building on the findings of the geospatial plan and a rapid readiness assessment, the Investment Prospectus proposes a year-by-year electrification program up to 2030 (including connections for schools and clinics) and details the investment needs, financing gaps and possible sources of funding with a focus on the first five years of implementation. The Prospectus also identifies key sector obstacles (related to the policy, institutional and financing frameworks) for the implementation of an access rollout plan and suggests possible areas requiring capacity strengthening through Technical Assistance.

As demonstrated by best practices in international experience, investments alone will not be sufficient to achieve universal access by 2030. They must be complemented by timely and effective enabling actions on several other fronts, especially the establishment of an enabling policy, targeted fixes to the institutional framework, and capacity strengthening of the key agents and institutions whose effective engagement is essential. Besides KEDCO, the Federal Government of Nigeria (Ministry of Power and of Finance, and the Office of the Vice President), the Regulator, and several other key stakeholders have a key role to play if electricity services are to be provided to over 80 million Nigerians currently living in the dark and ensure shared well-being across the country.

While the analysis and recommendations presented in this Volume reflect and respond to the operating context and specific characteristics of the KEDCO utility, they also provide an input for the completion of the bold sector reform launched by the Federal Government of Nigeria in 2010. While highlighting the make or break challenges for scaling up access in the Kano service area, the Volume also provides a roadmap for expanding access across the country in an efficient, effective, and timely manner.

Acknowledgements

This work could not have been possible without financial support from the Africa Renewable Energy and Access Program (AFREA), funded through the World Bank's Energy Sector Management Assistance Program (ESMAP)—a global knowledge and technical assistance program that assists low- and middle-income countries to increase their know-how and institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth. ESMAP is funded by Australia, Austria, Denmark, Finland, France, Germany, Iceland, Japan, Lithuania, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom, and the World Bank Group. AFREA's mandate is to help meet the energy needs and widen access to energy services in Sub-Saharan African countries in an environmentally responsible way. AFREA is funded by the Netherlands. The report also benefited from funding from the Sustainable Energy for All (SE4All) global initiative.

Under the overall guidance of Rahul Kitchlu (Senior Energy Specialist), the *Least Cost Geospatial Implementation Plan for Grid and Off-Grid Rollout (2015–2030) for the KEDCO Electric Service Area* was prepared by the Earth Institute at Columbia University School of Engineering and Applied Sciences whereas the *Investment Prospectus for the electrification of the KEDCO service area* by Economic Consulting Associates. Arun Sanghvi (Consultant) and Chiara Rogate (Consultant) supervised and coordinated the preparation of this Volume.

The team is grateful for the guidance provided by Rachid Benmessaoud (Country Director), Meike van Ginneken (Practice Manager, Africa Energy), Wendy Hughes (Practice Manager, Africa Energy), Rohit Khanna (Practice Manager, Energy Strategy and Operations), Erik Fernstrom (Practice Manager, Energy MENA) and Kyran O'Sullivan (Lead Energy Specialist). The team is also grateful to Sudeshna Banerjee (Lead Energy Specialist), Dana Rysankova (Senior Energy Specialist), and Yann Tanvez (Energy Specialist) for peer reviewing the reports and providing insightful comments, and to Jon Exel (Senior Energy Specialist) and Muhammad Wakil (Energy Specialist) for their valuable inputs. We would also like to thank Siet Meijer (Operations Officer) and the ESMAP team, particularly Heather Austin (Publishing Officer), Chita Obinwa (Program Assistant), Joy Medani (Team Assistant), and the colleagues in the World Bank Abuja Office for their support in preparing this Volume.

The team and the contractors would also like to thank the Management and staff of the Kano Electric Distribution Company (KEDCO) who provided strong and appreciated commitment, support and cooperation in the preparation of these reports.

PART 1

LEAST COST GEOSPATIAL IMPLEMENTATION PLAN FOR GRID AND OFF-GRID ROLLOUT (2015–2030) FOR THE KEDCO SERVICE AREA

ADVISORY SERVICE DOCUMENT
CONSULTANT SUMMARY REPORT

Contents

Figures

Tables

Executive Summary

This report for the first part of the Nigeria Electrification Access Program Development (NEAPD) summarizes results of geo-spatial least-cost planning for universal electricity access by 2030 throughout the service area for the Kano Electricity Distribution Company (KEDCO), Nigeria. This work has been undertaken by the Earth Institute, Sustainable Engineering Lab, working in close collaboration with KEDCO, supported by the World Bank under the Sustainable Energy for All (SE4ALL) initiative. This program emphasizes electricity access, the first of the three SE4ALL focal areas, the others being efficiency and integration of renewable energy technologies. The resulting access plan covers the whole of the KEDCO service area, combining grid and off-grid technologies, for the 2015–2030 timeframe. A key feature of geospatial least-cost plans is that they reflect local actual conditions. Their accuracy and effective implementation therefore requires the update of plans over time, as illustrated by international best practices. The update of GIS-based plans also provides a powerful monitoring system to track progress over the implementation of access programs.

KEDCO, headquartered in Kano City, has a coverage area including three states (Kano, Jigawa, Katsina) comprising a projected population for 2015 of roughly 24 to 25 million[1] in an area of approximately 67,500 km^2 (~26,050 mi^2). This access planning occurs within the context of KEDCO's recent privatization and related challenges, including: the long-standing need for additional electricity supply, the urgent need to improve revenue by distinguishing paying customers from non-paying electricity "consumers", and to provide grid access to large portions of the service area. Meanwhile, current growth estimates suggest that the total population of the three states will reach 34 to 35 million by 2030, adding around 2 million homes to the KEDCO service area. Considering these needs—connections for current and future homes without grid access, and improvements to informal or unmetered connections—a universal electrification program is estimated to require ~5–5.5 million new connections over the next 15 years, using a combination of grid and non-grid technologies.

This analysis provides a "planning grade" estimate of total costs and technical needs for universal electrification based on best available data. It is intended to support high-level planning and decision-making, including discussions among government agencies, utilities, and funding partners regarding budgets, policies, capacity building programs and other components of a multi-year electrification program. This analysis is not intended as an engineering design or construction program. Key uncertainties, particularly the completeness and accuracy of population datasets, limit the accuracy of modeling outputs. Furthermore, this analysis focuses on the total costs and technical needs for universal electricity access over the 2015–2030 period as an aggregate. The rate of implementation of this program, including the annual pace of household grid connections or solar home system provision, will depend upon yearly investments, capacity within the utility to implement large-scale grid roll-out, and other issues that are beyond the scope of this assignment. These factors are addressed in the investment prospectus, also supported by the World Bank.

The least-cost geospatial plan for scale up of electricity access in KEDCO's service area broadly outlines a program for achieving universal electricity access in a systematic, efficient and least-cost manner. Furthermore, the analysis and results of this report provide a geospatial and quantitative frame for the design and detailing of a well-coordinated and harmonized implementation program for grid and off-grid electrification over a fifteen-year timeframe (2015–2030).

Overall, the analysis confirms that—given the demographic settlement patterns and relevant technical, economic and financial parameters provided primarily by domestic, Nigerian sources—a grid roll-out-based strategy is the least-cost means to provide access to the vast majority of the population by 2030. The analysis in this report also indicates the potential and scope for an off-grid program—designed, harmonized and coordinated with the grid rollout program, with both geospatial and temporal targeting.

Both components of the access scale up and rollout program are discussed in the following sections of the Executive Summary.

ES1. Grid Electrification Program

Over the long term, grid extension is the least-cost electrification option for virtually the entire population (~97%) within the KEDCO service area. Table 1 below summarizes the components and costs for a ~$3.3 billion[2] grid extension program that will reach about 5.3 million households, resulting in nearly universal grid coverage, by 2030.

This fifteen-year grid extension program includes four components:

a. **Customers**: KEDCO estimates that it has ~400,000 pre-existing residential customers, representing 7% of the households projected for the service area in 2030. While these households already have KEDCO accounts and pay for service, 63% lack meters and pay a monthly flat rate. Meters for these homes will require an additional investment of around $40 million (~250,000 households at ~$160 per household[3]). Enumeration of all customers, including creation of a geo-located customer database, is among KEDCO's highest priorities as the utility works to improve revenue.

b. **Consumers**: KEDCO also has many grid-connected "consumers" which receive service but are neither billed nor pay for electricity use. KEDCO does not know the size of this component, so it has been estimated here using Living Standards Measurement Survey (LSMS) data to be about 840,000 households. This represents 22% of current households (2015) and will be 15% of service area households in 2030. In parallel with the effort

Table 1 Electricity access in 2015 and grid extension program for the KEDCO service area, 2015–2030

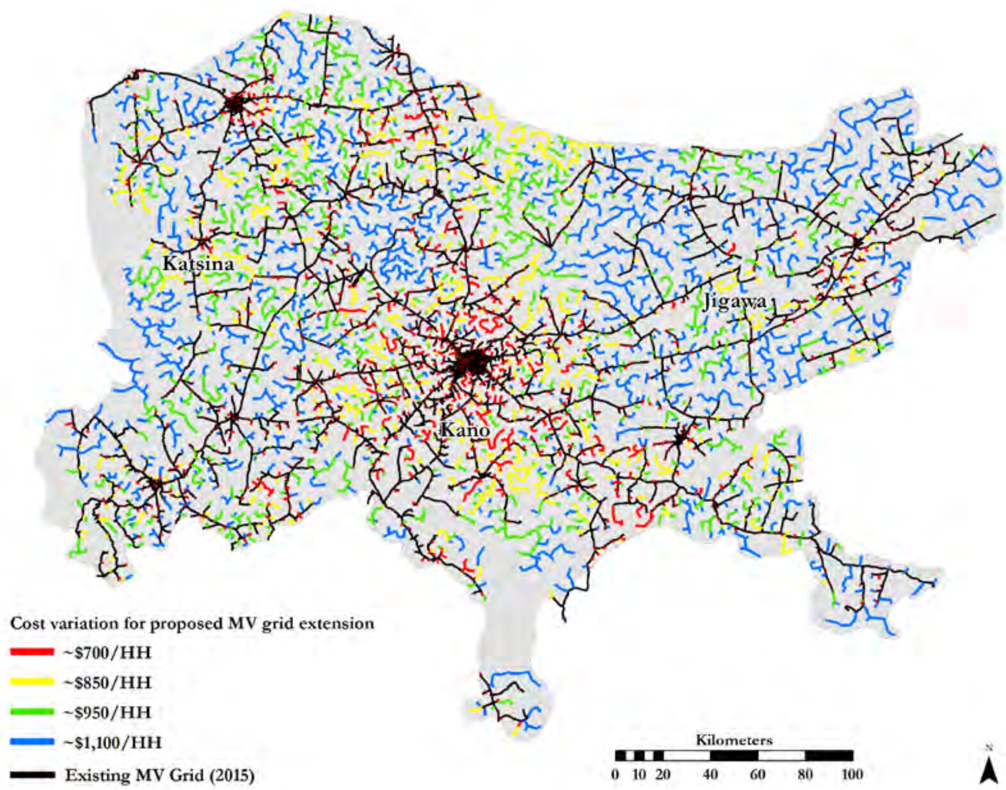
Electricity access status (2015)			**Grid extension program (2015–2030)**				
Type of access	**Population[a] (Households)**	**Percent**	**Components of grid program (Type of grid access planned)**	**Population[a,b] (Households)**	**Percent**	**Total CAPEX (M USD)**	**CAPEX per HH (USD)**
Grid access	7,430,000	31%	**A) Customers:** KEDCO has ~400K customers (2015); 63% need meters ($160/HH)	2,400,000 (400,000)	7%	$40	$160
	(1,240,000)		**B) Consumers:** ~840K HHs (2015 est.) consume power but do not pay KEDCO; all need meters & improved connections (~$180 per HH)	5,030,000 (840,000)	15%	$150	$180
No grid access	16,480,000	69%	**C) LV Intensification:** By 2030, ~2.7 M HHs near the grid will need LV line, meter, connection (~$630 per HH)	15,680,000 (2,670,000)	47%	$1,670	$625
	(2,750,000)		**D) MV grid extension:** By 2030 ~1.8 M more distant HHs (>1.5 km from transformer) will need MV and LV line, connection, meter (~$840 per HH)	10,560,000 (1,760,000)	31%	$1,470	$835
Total	**23,910,000** **(3,990,000)**	**100%**	**Total**	**33,670,000** **(5,670,000)**	**100%**	**$3,330**	**$590**[c]

[a] Based on census data, rural households have 6.1 persons on average vs. 5.8 for urban households. For simple computations and where the ratio of urban and rural households is unknown, 6 persons per household is assumed.

[b] It is assumed that population growth from 2015–2030 among those who currently have grid access (components A and B) will lead to net formation of new households that will need new connections requiring LV intensification (component C), MV grid extension (component D) or off-grid access.

[c] Average household costs are calculated by summing all CAPEX costs across all program components and dividing by the total number of households served.

Figure 1 **Existing grid lines and the prioritized grid expansion plan based on average cost per household for the KEDCO service area, 2015–2030**



to enumerate paying customers, KEDCO is also working to identify and convert these "consumers" into customers by improving connections and adding meters and accounts at a cost of ~$180 per household[4] (~$150 million total).

c. **LV Intensification**: This analysis estimates that, by 2030, 45% of projected homes will reside in locations that are currently within 1.5 km [5] of an existing transformer. KEDCO can connect these with LV extensions, service drops and meters, at an estimated average cost of ~$630 each, for a total of ~$1.7 billion for ~2.7 million households. This is the single largest component of the overall electrification program, both in number of households served and total costs. The accuracy of this estimate is likely to improve as KEDCO learns more about its customer database as it works to quantify components A and B.

d. **MV Grid Extension**: Households beyond 1.5 km range of a transformer will require extension of KEDCO's MV line at an estimated cost ranging from $730–1,100 (average ~$840) per household. This is the second-largest component of the electrification program, connecting ~1.8 million homes (~30% of projected households by 2030) for ~$1.5 billion.

Costs for homes that will be on the grid by 2030 can be summarized as follows:[6] Components A and B (Customers and Consumers) require only small expenditures for equipment like meters and improved connections, and so will likely cost less than $200 per household. Households connected through LV Intensification (Component C) require ~ $660 most for the meter, service drop, and LV line. These three components (A-C) target a total of nearly 4 million homes, which represents between 65 and 70% of the universal access program, all of which is expected to occur with little or no extension of MV line. Homes reached by component D) MV Grid Extension have the same local connection and low voltage costs as component C, plus the additional cost of medium voltage line

Table 2 Technical summary for the LV Intensification & MV grid extension components of the universal access program for the KEDCO service area, 2015–2030

	Number household grid connections proposed		Grid length proposed (km)				New generation needed (MW) for residential connections	
			MV grid extension			LV intensification	MV grid extension	LV intensification
State	MV grid extension	LV intensification	MV	LV	MV/HH (avg, m)	LV		
Jigawa	510,000	482,400	6,600	15,200	12.9	13,200	120	120
Kano	640,000	1,523,200	5,600	18,700	8.7	34,800	170	400
Katsina	610,000	664,400	7,000	18,200	11.4	17,000	150	160
Sub-total	**1,760,000**	**2,670,000**	**19,200**	**52,100**	**10.8**	**65,000**	**440**	**680**
Total	**4,430,000**		**136,300**				**1,120**	

extensions spanning distances between villages. This introduces substantial variation in per household connection costs in this component (D) due to geospatial factors such as the size and spacing between communities, resulting in a range of between about $700–$1,100 per household for only those households in the MV grid extension component.

This analysis includes a cost-benefit prioritization of MV grid extension based on the objective of meeting the most electricity demand with the least investment. In practice, this means prioritizing connections to larger communities closer to the grid first, then moving out to reach smaller, more distant, and more dispersed communities. High priority grid extensions in dense areas require less MV line per household on average (~5–10 meters) at a cost of $700–850 per household. For latter parts of the MV grid extension program that target increasingly rural and remote areas, a greater MV line investment per connection will be required (15–25 meters on average), leading to household connection costs averaging $900–1,200. Figure 1 above illustrates this prioritization, based on household connection costs, of grid roll-out for the KEDCO service area. While this map is not a construction design, it nonetheless provides insight into how grid extensions can be broadly prioritized and budgeted in a manner that responds to cost-benefit considerations. Note that the majority (~70%) of the KEDCO area homes lie within 1.5 km of the existing grid and can be connected to grid with no MV extension. The colored lines in this figure show MV grid extensions required to reach only the remaining ~30% of grid-targeted households that are beyond the range of the existing grid.

Table 2 below is a technical summary of the grid extension program by state, including number of connections, MV and LV line length, and new generation required.[7]

These data illustrate a few key conclusions of this analysis. The bulk of the new grid customers and 60% of the ~1.1 GW of new electricity demand will result from LV intensification—the process of connecting homes that are near existing transformers with only LV line—and the majority of this intensification will target Kano state, the most urbanized state within the KEDCO service area. The proportions are roughly reversed for MV network extension: about 70% of the MV extension is targeted for Katsina and Jigawa. Similarly, the estimated MV line needed per household is higher in Jigawa and Katsina (11–13 m) than in Kano (8–9 m). The vast majority—over 115,000 of the 136,000 km—of new grid line will be low voltage. In fact, the overwhelming majority (>90%) of the total grid extension program costs are low-voltage, local investments: Over $3 billion of the ~$3.3 billion total program cost will be for LV distribution lines, service drops, meters, and other costs of this "last mile" for access. In contrast, the medium voltage investments—the construction of 19,200 km of MV line spanning distances between communities—is estimated to cost only ~$310 million ($16/m), less than 10% of the of grid electrification program cost.

This grid extension program also implies a substantial increase in generation for the KEDCO area.

The program would add 5–5.5 million new residential customers to the KEDCO grid. It is estimated that each new household connection of average income would add about 1,200 kWh of electricity demand per household per year (requiring an additional ~ 400 peak Watts of capacity), while poor homes would add about half this, 600 kWh/year (~200 Wp). Poverty mapping data from an Oxford University study[8] commissioned by the World Bank was used to estimate the distribution of this range of household demand throughout the KEDCO service area and resulted in a weighted average household demand of ~840 kWh/year. It is assumed that each new KEDCO residential customer will add, on average, around 250–300 W of peak demand to the system (the weighted average is ~260 W). This will require about 1.1 GW of new generation,[9] nearly 700 MW of which would be due to new connections near the existing transformers ("intensification"), while the other ~450 MW would result from MV grid expansion.

ES2. Off-Grid Electricity Access

In parallel with and complementing the MV-grid extension program, this analysis provides a broad technical and geospatial plan that can serve as the basis for the future development of more locally specific and technically detailed designs for implementation of off-grid electrification. Broadly, this targets two types of beneficiaries:

A. Pre-electrification for communities that will wait several years for grid access

Potentially, the largest component of the off-grid electrification program consists of households and communities[10] which are targeted for grid connections in the latter part (beyond the medium-term) of the 15-year MV grid extension plan and thus will be required to wait potentially for several years (5–10, if not longer) for electricity access. This could be a large group of beneficiaries, although, the size, target areas, cost and timing of a pre-electrification program will eventually depend upon the actual implementation and sequencing of the rollout plan. These communities could be provided access in the interim with sufficient power for essential electricity services such as household lighting, and charging of mobile phones and other batteries and devices, and basic connectivity for schools and clinics to power computers, vaccine cold chain, and other services. Specific electrification technologies can be evaluated and selected—from options such as solar home systems and diesel or hybrid mini-grids—during a more detailed future program design.

B. Off-grid electrification for areas where grid is not the recommended least-cost option

This component is likely to be smaller than the pre-electrification component described above, and comprises two types of beneficiaries:

i. Very small and/or remotely situated villages that are unlikely to be cost-effectively served by grid connectivity within the next 15 years. These "long-term off-grid communities" represent a very small percentage of the total KEDCO service area (<1%) which will need non-grid power. As with the pre-electrification program described above, these would be served by a mix of solar home systems and appropriately sized mini-grids.
ii. Homes and small loads that are "isolated," meaning that they are more than around 100 m from any neighboring structure. These may, or may not, be far from the exiting grid, but their local isolation from neighboring structures raises the cost of grid connectivity greatly. These are expected to be most cost-effectively served by solar home systems, since the homes are too distant from neighbors to be connected to mini-grids.

Together, these two types of households targeted for off-grid electrification—those located in communities that will be reached by grid extension after many years, and those that are "isolated" households—represent ~3% of the projected 2030 population or about 165,000 households which are expected to be served by off-grid technologies for the foreseeable future.

An off-grid "pre-electrification" program targeting transitional off-grid areas—to provide basic power supply for essential needs to those households, communities, and institutions that would likely have to wait beyond the medium-term for a grid connection—merits consideration. It is also noteworthy that a transitional off-grid plan (segment A above) would require investment and related program cost that is additional to the overall least-cost grid rollout plan. For this reason, it is appropriately considered only following completion of the Investment Financing Prospectus (2015–2020), and following KEDCO's determination of its five-year rollout implementation plan, which will include geographically specific, annual rates of new connections. For example, if KED-

CO elect to undertake the lower costs extensions and connections in areas close to the existing grid first—those needing meters and/or LV intensification investments only—this would imply that the majority of the homes and communities that are potential targeted for "transitional" off-grid connections would occur within the MV Grid extension portion of the program (component D in Table 1 above). In a scenario targeting service for those for whom grid service would be most delayed, the areas initially targeted for transitional "pre-electrification" would likely be among those with the highest unit cost per connection (marginal unit costs form a rising curve, as presented in Figure 16). On the other hand, KEDCO's strategy for access scale up could well respond to other key drivers, as of yet undecided. Some of the key considerations include a target for the annual implementation rate of new connections over the period 2015–2020, to be geospatially identified and approved by NERC. This and other determining factors would need to be defined before the development of detailed local off-grid rollout plans. Another key consideration is the technical standards to which transitional systems would be built, since this would affect whether investments in mini-grid generation, distribution and metering equipment would be preserved or recovered once the grid arrives.

Endnotes

1. 2011 population projections are by the National Population Commission of Nigeria; these are then projected forward to 2015 and beyond in this analysis.
2. All costs throughout the text and tables of this document are in constant 2015 US dollars, unless otherwise noted.
3. Estimates of customer numbers and costs ($125 for single-phase meter and other small costs) were provided by KEDCO, October 2015.
4. These connections are expected to require more technical improvement in addition to meters.
5. KEDCO estimates 1.5 km as the radius within which customers can be connected without additional MV line.
6. A cost-buildup for household grid connections is provided in Table 12 on page 23.
7. This table reports the grid extension plan results with an "MV Correction Factor" which approximately doubles the length of MV line needed per household, adding about 15% to the total and per household costs of MV grid extension. This "correction factor" is described in Section 1.3 and Appendix A3.
8. Gething, P., Molini, V. (2015, June 10) Developing an Updated Poverty Map for Nigeria. Final Report. [No web address available]
9. Ensuring adequate electricity supply to all customers served by KEDCO is an urgent and important concern. As of 2015, peak supply to KEDCO was typically around 250 MW with occasional higher peaks. This is well below the 1 GW that KEDCO estimates to be its total current demand. The 1.1 GW demand forecast here would be a) only for residential needs, and b) in addition to any unmet current need.
10. The total number of households or communities targeted for pre-electrification will depend upon several factors that cannot be known at the time of this study, including the pace of grid expansion year-to-year, and the total funds available for these additional electricity systems.

Introduction

This document presents the final results for the geo-spatial electrification planning for the Nigeria Electricity Access Program (NEAP) – Technical Assistance (TA) conducted by the Earth Institute's Sustainable Engineering Lab (SEL/EI), supported by the World Bank under the Sustainable Energy for All program.[1] The partnership between SEL/EI and KEDCO has now completed task 6 as outlined in the initial proposal. The primary output will be this final report which discusses two broad activities: establishing a geo-spatial database and performing electrification modeling. In December 2014, the Earth Institute team provided an Inception Report, outlining various sources and approaches to obtaining key input data. In the months that followed, up to July 2015, the SEL/EI team established the geo-spatial database. This work is described in *Chapter 1 – Input Data and Parameters* and comprised the following three steps:

Mapping by KEDCO of its own medium-voltage (MV) grid distribution infrastructure, including ~10,000 km of lines, ~7,000 transformers, sub-stations and generation sites (completed July, 2015, see section *1.1. Mapping Medium Voltage Grid Line*).

Assessment and reprocessing of INEC polling unit data in comparison with data for the existing grid, satellite imagery and survey data. This work focused on three estimates: a) the number of non-paying "consumers" currently receiving service form the KEDCO grid; b) the number of "isolated" homes (>100 meters from the nearest neighbor); c) an "MV correction factor" to address the fact that locations of INEC polling units do not represent all rural towns and villages. (For details, see section *1.2. Geo-located Populated Places*).

Investigating and estimating a range of technical and cost parameters related to factors such as population and related growth, costs of electrification equipment, and electricity demand, incorporating patterns of poverty and wealth (see section *1.4 Model Parameters and Other Data Inputs*).

Working from this base of input data and parameters, the SEL/EI team has performed geospatial analysis to estimate the overall extent, cost and technical details of a grid and off-grid electricity system that would serve the whole population of the three states (Kano, Katsina and Jigawa) of KEDCO service area. This modeling effort and results are described in Chapter 2. Preliminary results were written up in draft form throughout April–June, 2015. This was followed by two trainings which took place in May, 2015—one in MV line mapping, targeting multiple utilities, and the other focused on data preparation and geo-spatial electrification modeling, targeting only KEDCO. This document provides a final, updated report of all work for this project.

Endnote

1. www.se4all.org.

CHAPTER 1

Input Data and Parameters

1.1 Mapping Medium Voltage Grid Line

A key input for electrification planning is geo-referenced data for electricity infrastructure, which is needed to quantify the spatial patterns of current access and costs for future connections. At project inception, the sources of information for KEDCO's grid distribution system were rough maps, single-line diagrams, or other resources that were sufficient for many utility operations but lacked geo-spatial detail needed for village-level access planning. To address this gap, SEL/EI provided a week-long training in the use of smartphones and open-source editing software (JOSM[1]) for data capture, editing and management to approximately 15 KEDCO staff in Abuja in December, 2014. This was followed up with remote technical support during the next 4–6 months, as KEDCO mapped the utility's grid assets, including ~10,000 km of MV Lines and 7,000 transformers (see Figure 2 below).[2]

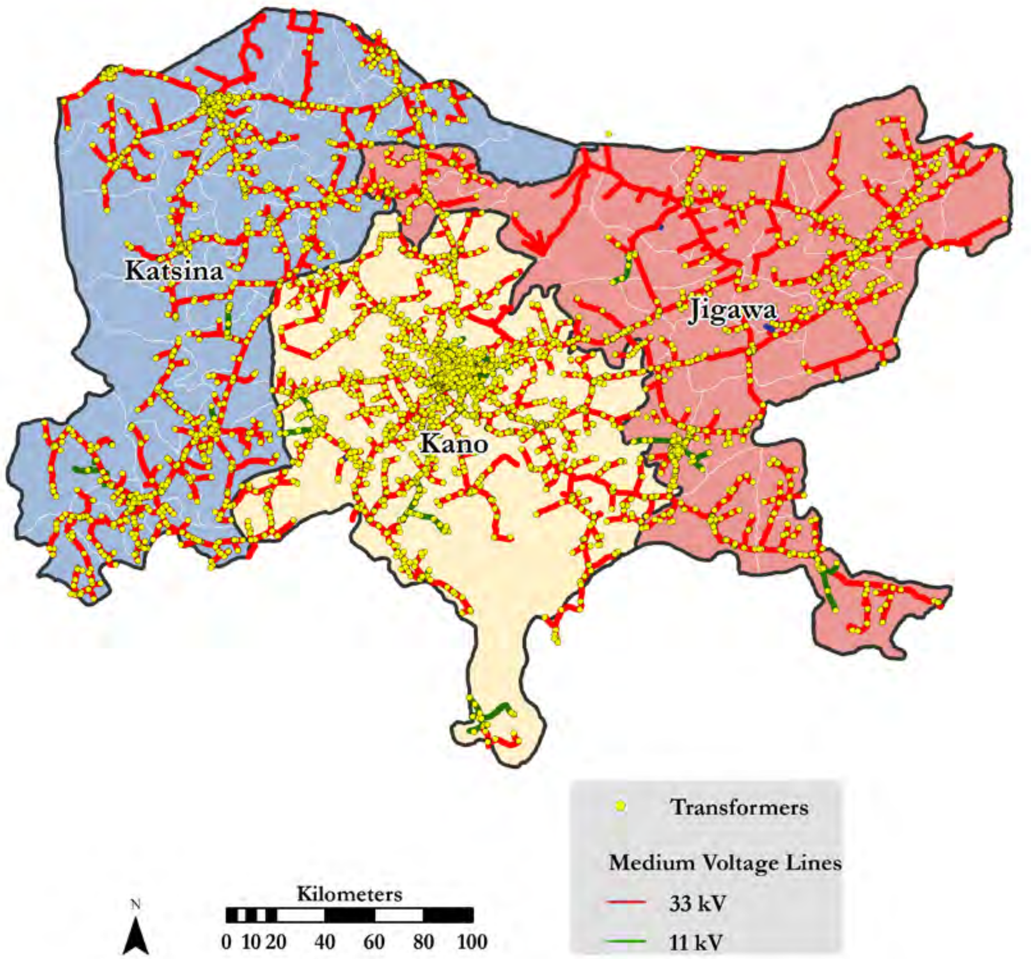
Some highlights and lessons from the KEDCO mapping:

- The entire effort required ~3–4 months of steady work, spread over approximately 8 months, including time for validation and gap-filling;
- Mapping employed ~12 team-vehicles (1 team per KEDCO business unit);
- One vehicle was able to cover ~10–100 km per day, depending on whether target areas were urban or rural (~10–30 km/day in urban areas; ~40–100 km/day in rural areas);
- KEDCO mapped ~10,000 km of MV line: ~4,300 km in Kano, ~3,000 km in Jigawa, ~2,700 km in Katsina;
- Latitude / longitude coordinates were collected for ~7,000 transformers and ~45 substations;
- The KEDCO service area is ~68,000 sq. km and has a total population of ~25 million (2015 est.[3]).

This commendable effort by KEDCO merits attention for the aspects of implementation that contributed to its speed and success.

- **KEDCO leadership provided firm and consistent support for the program**: Grid mapping is a labor- and resource-intensive exercise, requiring sustained engagement of many layers of utility staff across the full service area. The commitment of vehicles, fuel, and labor for fieldwork, as well as the office work required for data editing and validation, necessarily compete with other budgetary priorities and duties. These factors often lead utilities to stop mapping efforts before completion or validation. Given this risk, it was fundamentally important that support from KEDCO's top management was consistent throughout and articulated clearly to all levels of staff engaged in the effort. In addition, mapping was not outsourced, as is often the case, but rather executed entirely by KEDCO staff. This ensured that KEDCO absorbed new technical capacity (skills, software, data-gathering tools like smartphones and laptops) while retaining control of the pace of work and quality of the resulting map data.
- **KEDCO management multiplied the workforce and pushed the mapping effort**: In many projects, mapping is attempted by small teams of GIS or mapping specialists, whether consultants or utility employees. This tends to restrict the mapping team to a small group, slowing overall progress, which in turn causes many utilities to

Figure 2 MV grid line and transformers coverage in the KEDCO service area, July 2015



cease mapping long before the work is complete. In contrast, the SEL/EI team has found that mapping work proceeds better if the utility broadens the mapping workforce, involving technical staff at several levels of the utility's hierarchy, and including technicians from all geographic areas who can provide locally informed guides to mapping teams. KEDCO's planning department recognized early this need to "multiply the workforce" for grid mapping, and quickly ensured that those trained in Abuja passed on their new skills to others in each business unit. This increased the number of trained mappers and data editors by roughly a factor of three, ensuring that each of KEDCO's 12 business unit had at least one full team of mappers and data editors. Then, KEDCO central management supervised progress, while driving data collection teams with frequent reminders and supporting the efforts of field teams by phone and in person. There was an element of competition among business units, as the planning department released weekly reports of teams' performance.

- **Cloud-based data platform enabled better supervision and technical support**: Typically, mapping projects encounter difficulties with the use of GIS software, particularly problems with sharing and collaboratively editing shapefiles. These include problems with organizing and supervising mapping work, such as duplication and omission of feeders or equipment; difficulty sharing map data and preserving "version control" as multiple shapefiles are merged and edited; and difficulty "seeing the bigger picture" when map

Figure 3 **Left: KEDCO engineers labeling and correcting data for MV grid infrastructure using JOSM editor. Right: A KEDCO engineer in training to map MV line infrastructure using a smartphone**

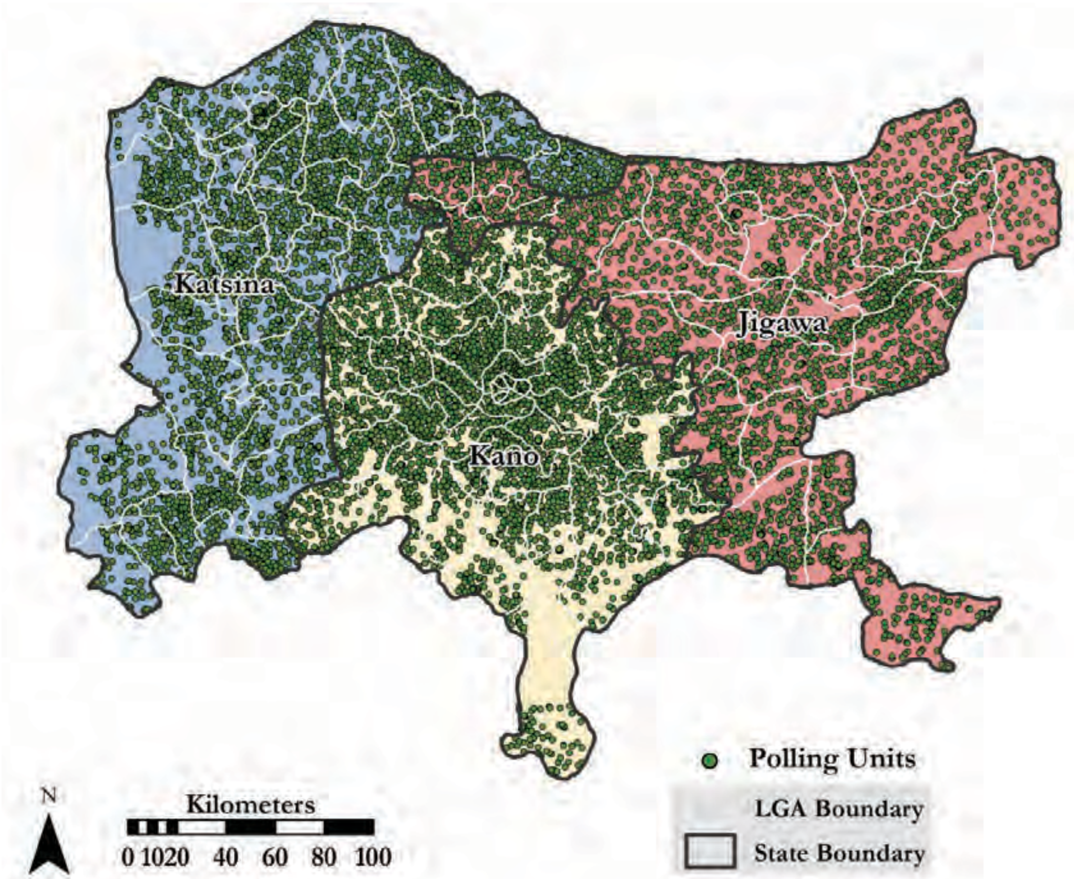
data are restricted to one or few staff computers. To address these issues, KEDCO's mapping effort ensured that newly gathered map data was uploaded to a cloud-based platform that could be viewed in KEDCO field offices, Kano City headquarters, and by SEL/EI staff in New York. This allowed multiple users to review, integrate, correct, and validate map data in a collaborative fashion as it was collected. This avoided the common pitfalls listed above, while facilitating remote work among KEDCO headquarters, field offices, and the SEL team in NYC. Overall, this greatly accelerated the identification and resolution of technical problems and validation of data.

As this mapping effort came to a close, the Earth Institute/SEL team provided additional training (Abuja, March 2015) on validating the grid data and basic GIS skills. This training also introduced the KEDCO team to SEL/EIs modeling approach and software (NetworkPlanner) and allowed the SEL/EI and KEDCO teams to discuss and refine key model parameters. In May and June, 2015, SEL/EI and KEDCO used this new MV grid distribution system map as a key input to the technical and cost modeling to support planning for expanded grid and off-grid access throughout the KEDCO service area. Also in May, KEDCO mappers and planners joined the SEL/EI staff as part of the training team in a national workshop to enable other Nigerian electricity distribution companies[4] to use this same mapping approach, supporting Nigeria's capacity to establish a national distribution map with common features as a step toward geo-spatial, data-driven planning as a national standard. By June, 2015, data gaps in the MV grid map were resolved, specifically for the northern portion of Katsina State, thus completing the map of KEDCO's MV system.

The entire grid mapping effort spanned approximately 8 months, but took place in bursts of intensive activity spanning perhaps 3–4 months. The final stages of data review, in preparation for technical and cost modeling, emphasized the importance of validating the dataset. In May and June of 2015, problematic results in preliminary model runs and validation efforts clarified gaps in MV line maps, and these were resolved in June and July, 2015, leading to the final results presented here. The key lessons learned and future steps of grid and possibly other infrastructure mapping is discussed in the Summary Report document for this NEAP project.

Considering future uses of this data and system, KEDCO recognizes the value of this map over the longer-term, as it allows an updated and accurate measure of the system's line length. It also provides a starting point for a data-driven approach to other important KEDCO concerns, such as load flow analyses and establishing a customer database.

Figure 4 INEC polling sites throughout the three state KEDCO service area, 2015



KEDCO plans to continue to validate, expand, and maintain this power line dataset for its growing network to support future planning and maintenance. Several other utilities have also responded favorably to this mapping approach, seeing it as a low-cost, convenient method to establishing a basic map of utility assets to serve future planning.

1.2 Geo-located Populated Places

An essential input data type for this modeling approach, and particularly for planning electricity access for the underserved rural areas, is geo-located populated places. Because this project also aims to quantify needs for small, off-grid communities, population data that extends down to the level of individual villages is ideal. There is currently no known source of comprehensive, accurate, village-level, geo-located population data for the KEDCO service area; however, voter registration data offers a useful proxy.

Polling Unit Data: A Proxy for Village-level Population Data

While the inception report noted various potential sources of demographic data in Nigeria, the most comprehensive, highest resolution and most validated data source currently available has proven to be the national voter registry created by Nigeria's Independent National Electoral Commission (INEC)[5]. The three states of the KEDCO distribution area (Kano, Katsina and Jigawa) contain about 16,000 polling sites, out of a total of 120,000 nationally. These serve approximately 10 million voters, or an average of 600–650 voters per site. This compares with a total population for the three states of about 19 million (Kano 9.4, Katsina 5.8, Jigawa 4.3 mil-

Figure 5 **Satellite imagery (Google) for part of Jigawa state shows correspondence between INEC polling sites (green points) and clustered structures indicating locations of communities**

lions), according to the 2006 census, and ~25 million in 2015.[6]

Figure 4 above illustrates that polling unit data is comprehensive throughout KEDCO's service area, with apparent gaps in western Katsina and southern Kano corresponding to protected areas or reserves. Similarly, as Figure 5 below shows, there is often a close match between polling unit locations (green points) and human settlements, particularly larger villages, which are easily identified in satellite imagery.

However, Nigeria's polling unit data is not a census, and thus is only a proxy for geo-located population. The issues related to its use are described below.

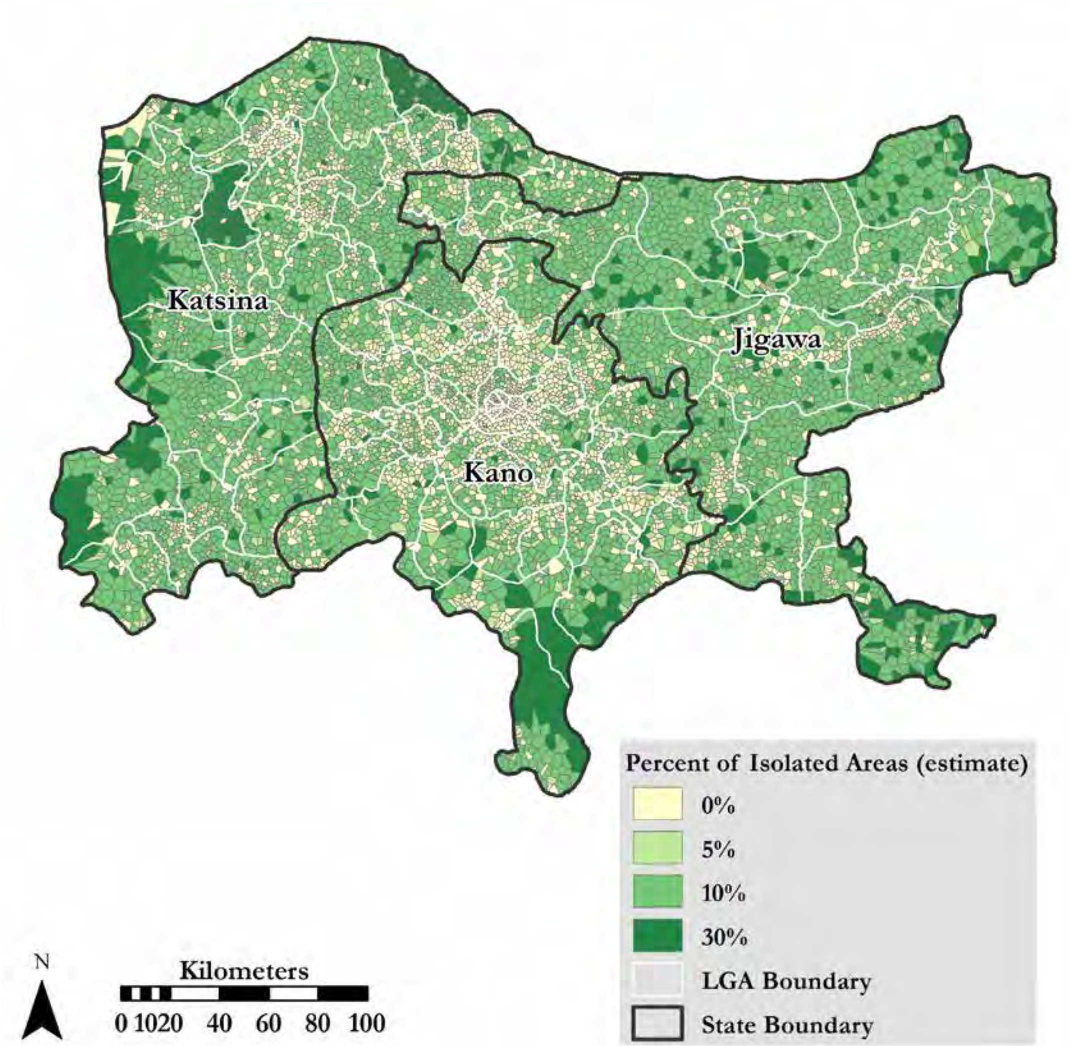
Corrections and Estimates Related to Polling Unit Data

Polling unit data required substantial pre-processing to address differences between the locations and number of voters recorded for each polling unit versus the locations and number of residents of populated places. These pre-processing steps used a combination of quantitative and GIS analysis, the results of which are summarized below and described in greater detail in *Annex A – Pre-processing of Electricity Demand Point Data*.

Conversion of registered voters into populations: Individual polling unit records list only the number of registered voters, and so require conversion to estimate a population count. The conversion performed here employed a combination of census information for populations and growth rates, as well as geospatial information defining urban vs. rural areas based on the "night lights" satellite dataset[7]. The detailed method is described in *Annex A1 Derivation of Population based on Registered Voters at Polling Units*. Figure 6 below shows urban and rural extents derived from "night lights" data. There is a clear correspondence between areas identified as urban using night lights (yellow boundaries) and areas that have high population density as reported in the 2006 Census (darkest green polygons).

Estimation of the percentage of isolated households: Second, particularly in sparsely populated rural areas, a single polling place may serve populations which are in fact dispersed (see Figure 7 below). This dispersal may be either among multiple separate small villages or "isolated" households, which in this analysis are defined as those more than 100 meters from their nearest neighbor.

Figure 6 Population density at LGA level (2006 Census) combined with urban boundaries as defined by the "night lights" satellite dataset shows correspondence of high density and urban areas



To correct for this, SEL/EI used satellite imagery to estimate the percentage—ranging from 5% to 30%—of isolated homes in each of the ~16,000 polling units throughout the KEDCO service area. The method is detailed in *Annex A2 Estimating the Frequency of "Isolated" / Off-grid Households*. The geo-spatial result is presented in Figure 8 below which shows the percentage of isolated households using a grayscale for each polling unit coverage area. Note the correspondence between areas with lower estimated frequency of isolated households in Figure 8 and the urban areas shown previously in Figure 6, as well as the higher estimated percentage of isolated households in rural, low-density areas.

The quantitative results of this analysis are presented in Table 3 below. A small percentage of the total population (a bit less than 3%) have been identified as "isolated", starting at ~126,000 households in 2015 and growing to around 164,000 in the 15 years from 2015–2030. Also, as evident in Figure 8 above, the vast majority of these isolated households are in rural areas (>99%).

Estimation of a "Medium Voltage Correction Factor": Another potential modeling error arises from

Figure 7 **One polling site (yellow point, left) serves a widely dispersed population (households marked with blue points). Some of these are clustered into neighboring villages that lack a polling site (upper center of image); others are "isolated" households, more than 100 meters from their nearest neighbor (periphery of image)**

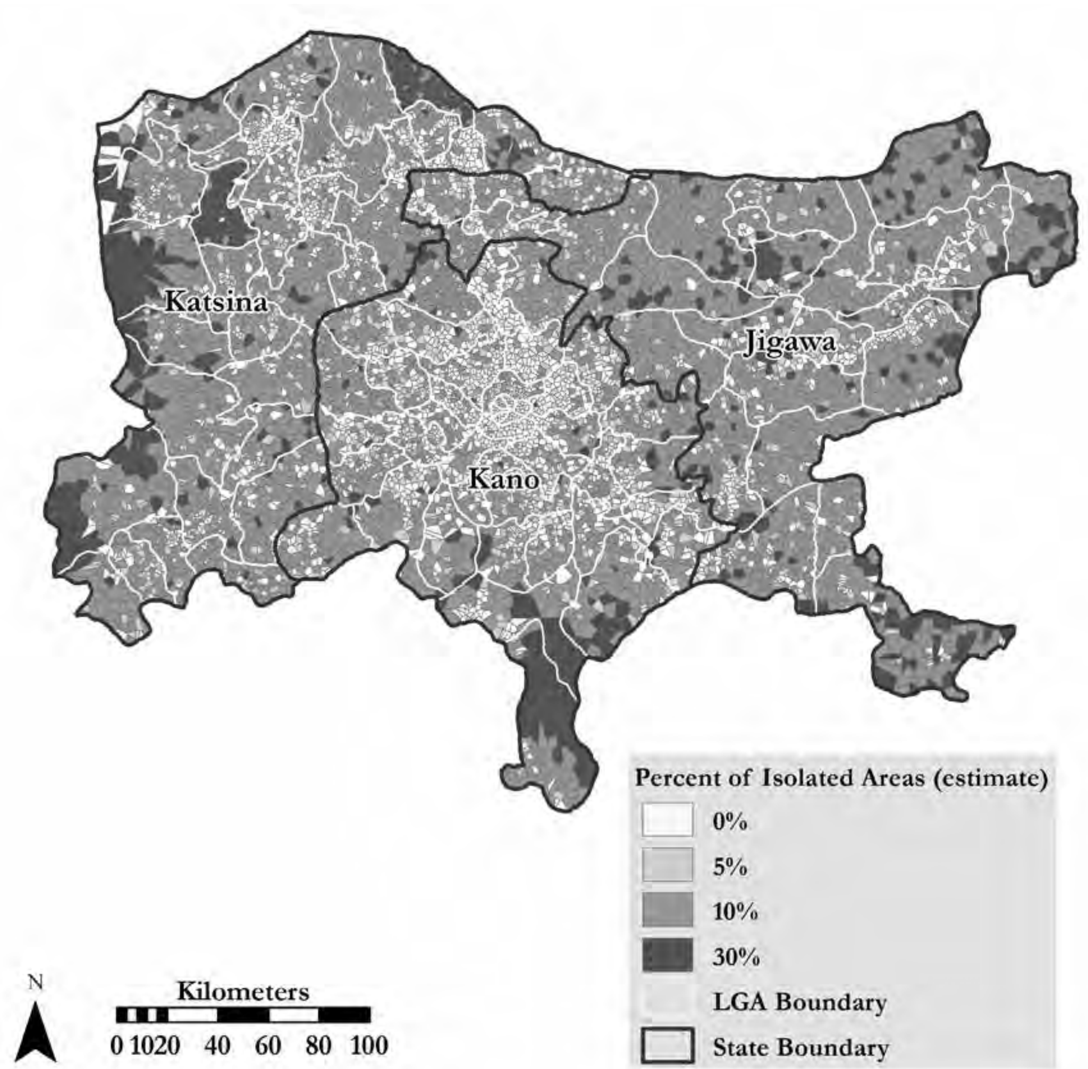
the fact that not every village has its own polling site. Instead, voters from multiple separate villages are assigned to vote at a single polling site that may be a significant distance from households and other points that need electricity. Since these separate villages would most likely be served by their own MV grid lines, the total MV line needed for an actual grid extension program will exceed the length predicted by modeling with polling unit points. This effect is illustrated in Figure 9 below, with a solid red line showing the grid recommended for villages accurately represented by polling units, while the dotted line illustrates an MV line to serve villages which lack polling sites.

A rough estimate, described in detail in *Annex A3 Estimating the "Medium Voltage Correction Factor"* suggests that the additional MV line required to reach these villages that have no polling sites will increase the total MV line needed throughout the KEDCO coverage area by factor of 2. The technical implications of doubling the total MV length of the grid extension program are clearly significant,

Table 3 **Population estimates for "isolated" households through the KEDCO service area (2015–2030)**

	2015			2015–2030 (with Pop. Growth)		
	Population (Households)	% of KEDCO area population	Urban/ Rural population	Population (Households)	% of KEDCO area population	Urban/ Rural population
"Isolated" (SHS recommended)	830,000 (126,000)	3%	Ur: ~5,000 Rur: ~825,000	985,000 (164,000)	3%	Ur: ~6,000 Rur: ~979,000

Figure 8 **Estimated frequency of "isolated" households (suitable for off-grid technologies) for all polling unit areas in the KEDCO service area**

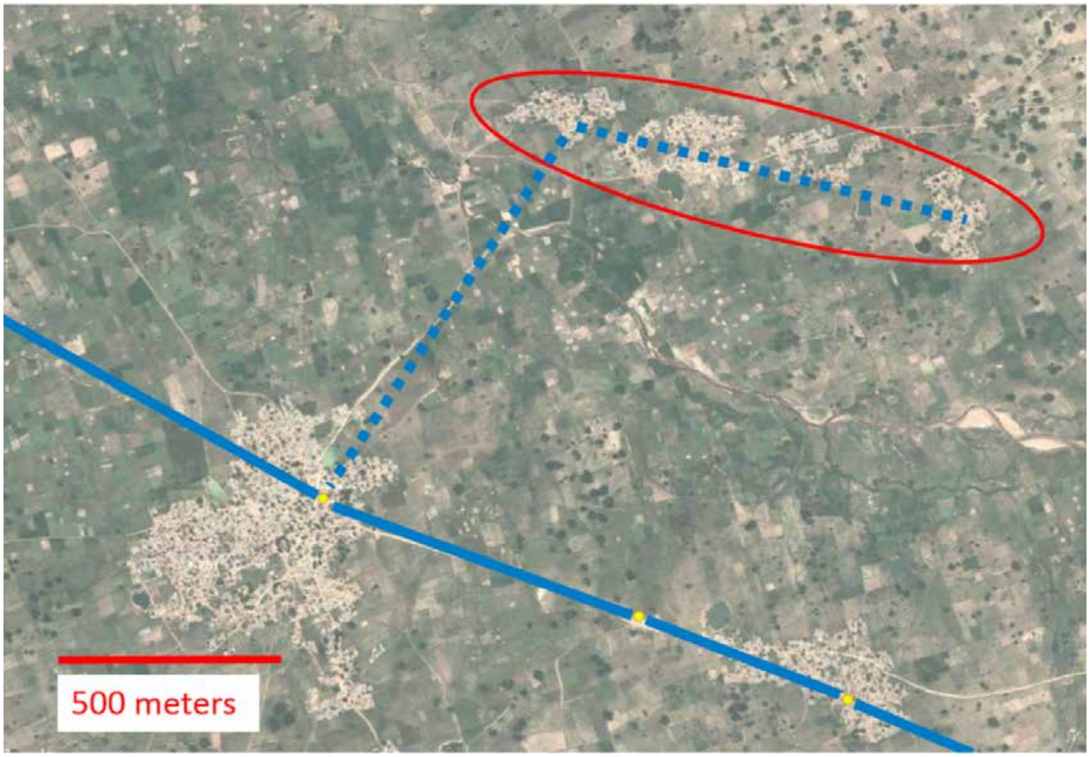


but this does not change the overall cost outcome of the analysis fundamentally. The reason for this, as stated previously, is that the bulk of the grid access program's costs (90%) arise from local, low-voltage distribution and connection. A doubling of MV-related costs only increases the total cost of the full grid access program by around 5%.

Estimating grid penetration: Since the breakup of the national power company, Power Holding Company of Nigeria (PHCN)[8], KEDCO and other recently privatized utilities throughout Nigeria face a challenge in quantifying the current state of grid access, commonly referred to as "penetration". This includes two main categories of existing or potential connections:

1. "Customers" (connections with KEDCO accounts): KEDCO estimates that as of 2015 it has ~400,000 customers.
2. "Consumers" (those connected to and consuming power from the grid, but who do not pay for service): KEDCO says the number of customers is unknown, but estimates that the number is 2–3 times as large as the number of customers.
3. Households reachable with "intensification":

Figure 9 Solid blue lines show MV needed to reach villages represented by polling sites (yellow points); the dotted blue line shows the extra MV line needed to reach villages without polling sites



households within a 1.5 km range of existing transformers but currently without grid access are reachable with LV extensions and connections. KEDCO has no estimate of the number of households in this category.

The utility is working urgently to establish an accurate database of existing customers while launching a program to convert non-paying consumers into paying customers by improving connections, installing meters, and establishing accounts. However, substantial progress on all of these goals is likely to require at least one year. In the meantime, to estimate the number of households in the second and third categories, the SEL/EI team conducted a geospatial analysis that combined three data sources: (i) the locations of recently-mapped transformers; (ii) polling place data as a proxy for population; and (iii) Nigerian LSMS data regarding grid electricity access in the home. A key assumption in this analysis is the 1.5 km distance from a KEDCO transformer to a household that still permits connection with only low-voltage line extension.[9] The steps in this analysis are described in detail in *Annex A4 Estimating Grid Penetration,* and the results are summarized in the following section.

1.3 Components of a Universal Electrification Program

The combination of geo-spatial data, estimates of grid-connected and isolated households, and correction factors establishes the basis for modeling by placing households in categories based on whether they are connected to the grid, and how distant they are. This physical description serves as a basis for defining the categories (or "components") of a national electrification program. This analysis considers grid and off-grid electrification programs separately.

Grid Extension Program

Table 4 below provides estimates of the number of households that fall into each of these categories, using population values for 2015.

Table 4 Electricity access status and four components of grid electrification program for the KEDCO service area (2015)

Electricity access status (2015)			Four components of grid extension program (2015)	Population (households)	Percent
Connected to grid	**7,430,000 (1,240,000)**		**A) Customers:** pre-existing KEDCO Accounts	2,400,000 (400,000)	10%
			B) Consumers: need KEDCO meters & accounts	5,030,000 (840,000)	21%
Not connected to grid	**16,480,000 (2,750,000)**	**Within Range of Transformer (<1.5 km)**	**C) Intensification:** need only LV & connection	7,690,000 (1,290,000)	32%
		Outside Range of Transformer (>1.5 km)	**D) Grid extension** need MV, LV & connection	8,790,000 (1,460,000)	37%
Total	23,910,000 (3,990,000)		**Total**	23,910,000 (3,990,000)	100%

Reading the table from left to right, it first divides the 2015 population into those connected or not connected to the grid. Then, based on the kind of connection or the proximity or distance from the grid, it defines the four categories of existing and potential grid connections. Of those that are connected, about one-third (or 400,000 households) can be categorized as (A) "customers": those households with formal grid access which currently receive and pay KEDCO for service. Another 840,000 estimated homes are in component (B) "consumers" which have informal grid access and receive KEDCO service but do not pay. The ~2.75 million homes that are not currently connected to the grid fall into two more categories. Those within 1.5 kilometers of an existing transformer are placed in category (C) "LV intensification' meaning that they can be connected through extension of only the low voltage (LV) grid at relatively low cost. Those households more than 1.5 km from an existing transformer fall in category (D) "MV extension" meaning that they require addition of medium voltage line to reach the community, as well as all the LV and connection investments that apply for category (C). These data match the columns labeled "Electricity Access Status (2015)" in Table 1 from the Executive Summary.

This breakdown provides a few important insights. It appears that ~60% of the population (components A, B and C) within the KEDCO service area either already has grid access, or can obtain grid access relatively quickly and inexpensively, with only LV extensions and connections.[10] There is nonetheless a large group, probably ~37% (component D) of the grid electrification program that will require extension of the MV grid line.

Further analysis considered these geospatial patterns for population and grid location data for 2015 throughout urban and rural areas served by KEDCO. Table 5 below highlights differences in the penetration rate between urban and rural areas yielding a few important observations. The vast majority of the KEDCO area's urban population (98%, or about 5.2 million) is within range of transformer. This leaves only 140,000 urban residents who require extension of the MV grid. In contrast, only half of the rural population (8.8 out of 16.7 million) is within 1.5 km of a transformer; the rest will require MV grid extension.

Note that much of the information in the two preceding tables is based on estimates, rather than verified counts. The estimates are based on a combination of geo-spatial datasets and criteria—such as urban/rural discrimination performed using night lights data and KEDCO's somewhat informal designation of 1.5 km limit for LV extension—that are essential for electrification modeling and provide information that was not obtainable from more standard sources within Nigeria.

The final important step in preparation of the geo-spatial data for modeling is to project these 2015 population values forward to 2030, the final year of this planning exercise. Table 6 below presents the projected populations and household numbers for the categories defined in Table 4, with a few important assumptions. It is assumed that population growth from 2015–2030 among those who currently have grid access (components A and B) will

Table 5 Estimates of population in various categories (in range of current grid, requiring grid extension, and "isolated") in the KEDCO service area (2015 projected data)

Grid access estimates (2015)		Total (urban + rural)		Urban		Rural	
		Population	Percent	Population	Percent	Population	Percent
Within range of transformer (<1.5 km)	Connected to grid	7,400,000	31%	3,400,000	54%	4,000,000	23%
	Not connected to grid	7,700,000	32%	2,800,000	44%	4,800,000	27%
Outside range of transformer (>1.5km)		8,800,000	37%	140,000	2%	8,700,000	50%
Total population		**23,900,000**	**100%**	**6,300,000**	**100%**	**17,500,000**	**100%**

lead to net formation of new households that will need new connections requiring LV intensification (component C), MV grid extension (component D). In other words, components A and B do not show population growth from 2015–2030, because this population will "spill over" into categories C and D. Also, population growth generally is modeled based on census information regarding urban and rural growth rates. Projections for this analysis utilize those growth assuming that the incorporate factors such as internal migration, differential fertility in urban and rural populations. That is, we have made no additional assumptions about how populations move among categories. Finally, based on census data, rural households have 6.1 persons on average vs. 5.8 for urban households. For simple computations and where the ratio of urban and rural households is unknown, 6 persons per household is assumed.

The most important conclusion to be drawn from this table relates to the size of the future grid extension effort. Once population growth is considered, the total of homes newly connected to the grid is estimated to reach 4.4 million by 2030 (as opposed to 2.75 million estimated to need connections in 2015). It is crucial for utilities to keep in mind that, however daunting the task of reaching the ~70% of homes that are currently unconnected, this population will nearly double in an additional 15 years.

Table 6 Electricity access in 2015 and grid extension program for the KEDCO service area, 2015–2030

Electricity access status (2015)			Grid extension program (2015–2030)		
Type of access	Population (Households)	Percent	Components of Grid program (Type of grid access planned)	Population (Households)	Percent
Grid access	7,430,000	31%	**A) Customers:** KEDCO has ~400K customers (2015); 63% need meters ($160/HH)	2,400,000	7%
				(400,000)	
	(1,240,000)		**B) Consumers:** ~840K HHs (est.) consume power but do not pay KEDCO; all need meters & improved connections (~$180 per HH)	5,030,000	15%
				(840,000)	
No grid access	16,480,000	69%	**C) LV Intensification:** By 2030, ~2.7 M HHs near the grid will need LV line, meter, connection (~$630 per HH)	15,680,000	47%
				(2,670,000)	
	(2,750,000)		**D) MV grid extension:** By 2030 ~1.8 M more distant HHs (>1.5 km from transformer) will need MV and LV line, connection, meter (~$840 per HH)	10,560,000	31%
				(1,760,000)	
Total	**23,910,000**	**100%**	**Total**	**33,670,000**	**100%**
	(3,990,000)			**(5,670,000)**	

Off-Grid Electrification Program

Two subcomponents are broadly distinguished within the off-grid program.

A. *Pre-electrification in Transitional Off-grid Areas*

This component of the off-grid program potentially targets "transitional areas" to meet the needs of households and communities as they await grid rollout. The total size, scope, and cost per household of a transitional off-grid program will be determined based on numerous factors unknown at this time, such as the expected pace of grid construction, the availability of funds for off-grid investments, and the service standard (kWh per year supplied). As the KEDCO grid extends to a growing population of more than 4 million homes over the 15 years between 2015 and 2030, in any realistic implementation timeline a substantial number of households would likely wait 5, 10, or more years for grid connectivity. The homes that would wait the longest probably fall within the MV Grid extension program (component D in Table 6 above). Many of these would be good candidates for some sort of transitional, off-grid electrification, using technologies such as solar home systems and mini- or micro-grids. The pool of potential beneficiaries is so large that service for even a fraction of these homes with modest solar home systems, at a cost of perhaps $150–$200 per household, would result in a program cost of hundreds of millions of dollars. It is essential to note that the transitional off-grid systems would be in addition to all other investments described in the grid extension program (components A-D), and at least some aspects of these installations, possibly the majority, would be temporary. It is unknown at this time what proportion of the transitional off-grid investments would be recoverable once the grid arrives, and this will certainly depend upon factors such as whether infrastructure such as local LV distribution networks are built to utility standards, and whether elements such as solar panels could be moved and reinstalled elsewhere.

B. *Off-grid Electrification – Areas Where Grid Is not Least Cost*

A second component of the off-grid program would target "isolated" households and communities which cannot be cost-effectively served by grid, and so would need off-grid service for the foreseeable future. As described previously (see Table 3), a small, but significant portion (~3%) of the population—about 830,000 people in 2015, or 980,000 by 2030—are estimated to live in "isolated" households that are more than 100 meters from the nearest neighboring structure. Another even smaller population lives in communities in which households may be tightly clustered but, due to a combination of low total demand and distance of the community from existing and proposed grid, are not viable for grid extension. Both of these populations—isolated households and remote communities—will be most cost-effectively served by solar home systems or similar non-grid technologies.[11] This more permanent off-grid component is much smaller, totaling between about 130,000 and 170,000 households, depending upon population growth.

1.4 Model Parameters and Other Data Inputs

Gathering Modelling Parameters from Local Sources

A fourth key type of information includes the numerous parameters related to equipment costs, technical specifications, growth rates, and other details required for modelling grid and off-grid costs and technical needs. These parameters have been acquired in various ways, such as conversation with the utility, field visits and international sources. The Earth Institute team gathered many of these during the March, 2015, training visit, and refined them in discussion with KEDCO staff throughout the following 2–3 months.

Electricity demand per household is among the most important parameters for modelling purposes, but it is also often difficult to obtain conclusive data for this metric. KEDCO officials and engineers provided current electricity demand values ranging from a low of 600 kWh per household per year, to a high of around 1,200 kWh/HH-year.[12] This range was validated through a number of steps. KEDCO applies a "life-line" tariff for households consuming up to 50 kWh per month, the lowest tier residential customers categorized as "R1" (see Table 7 below), marking a lower end of this range at 600 kWh per year. The upper end was determined in part through discussion with KEDCO staff and in comparison with international results, which tend to range from about 1,000–1,200 kWh per year for households that use electricity for services such as rice cooking that are beyond the minimal needs for lighting and

Table 7 Nigerian Electricity Regulatory Commission (NERC) residential retail tariff classes, Multi-Year Tariff Order (MYTO), 2014

Customer classification	Description
Residential	
R1	Life Line (50 kWh/month maximum
R2	Single and 3--phase
R3	LV Maximum Demand
R4	HV Maximum Demand (11/33 kV)

phone charging. Finally, this range was compared with income and expenditure data from the LSMS data for Nigeria, which showed a factor of two between poor and richer household expenditures for energy overall. Based on this range, demand for a "poor" residential customer was estimated to be 600 kWh per year while non-poor households were assumed to consume twice as much electricity, or 1,200 kWh per year.

Other key grid cost and technical parameters[13] are illustrated below (for the full list of more than 70 parameters and their sources, see *Annex B – Model Parameters*):

- MV line: US$16,000 / km
- LV line: US$12,600 / km
- Distribution losses: 15%
- Connection cost: US$250 (this is an average for single and three-phase connections, including a $75 connection cost for labor and administrative work to establish a new connection and account, plus $175 equipment costs, for the meter and service drop)
- Cost of power: US$0.16 per kWh

The last of these cost parameters, the US$0.16 per kWh "bus bar" cost of power, is of fundamental importance. Briefly, it represents all costs of generation and transmission to deliver power to the medium-voltage substation, considering the full mix of existing and new generation, across all technologies including hydropower, gas turbines, and others, as well as all costs for existing and new transmission, including losses at this HV level. It represents the internal cost of power for the utility, not the final retail price of power to the consumer.

For diesel gensets, cost of fuel is a dominant recurring (and lifetime) cost:

- **Diesel Fuel: US$0.87/liter**

Costs for solar systems were obtained from a combination of sources, including renewable energy specialists with the Federal Ministry of Power and compared with international prices.[14]

- **Solar PV panels: US$0.80 per Watt-peak.**
- **Batteries: US$150 per kWh; with 3 year lifespan.**

Household size was derived for each state or region using the data reported in the Population and Housing Census Priority Tables by the National Population Commission of Nigeria based on 2006 Census, which included both the number of households, and the total population for a given community.

Poverty Mapping

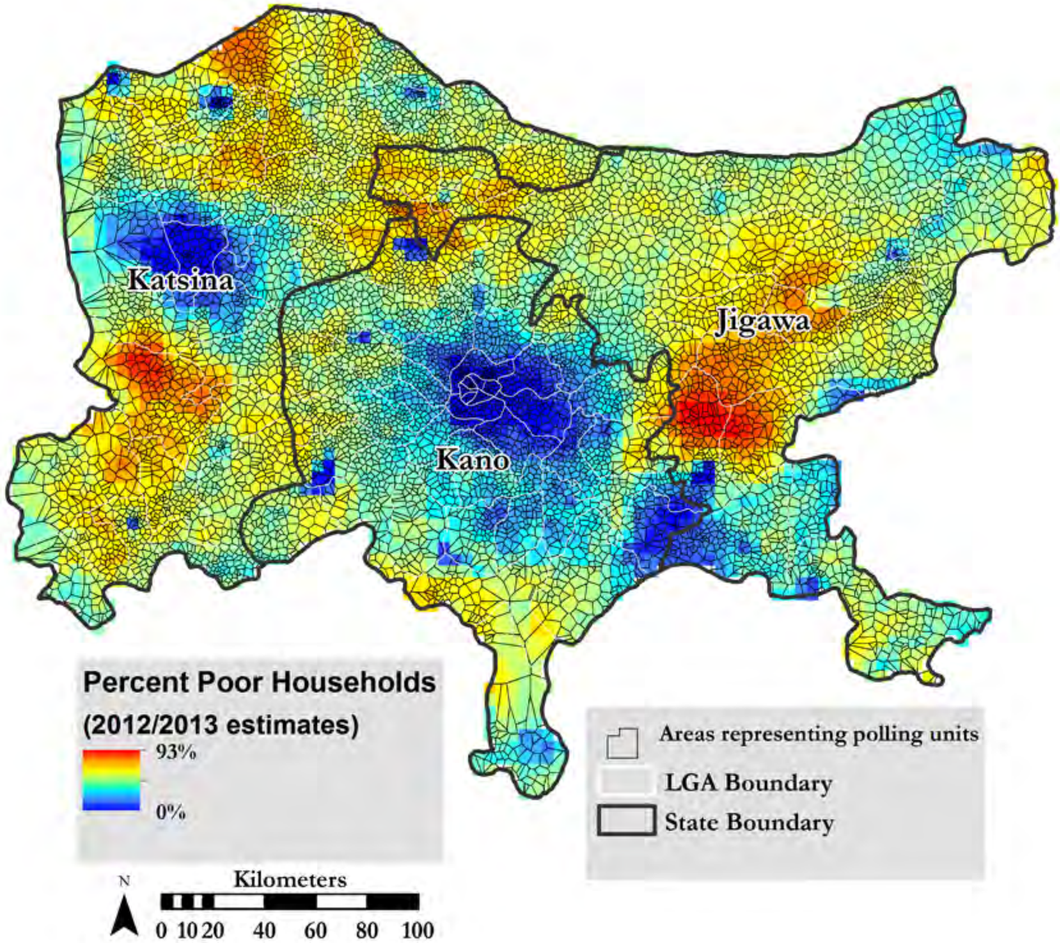
Poverty and wealth mapping information can be used in a variety of ways to address goals of shared prosperity in national electrification planning. One is to add spatial nuance to estimates electricity demand. Data on household and community income, assets and expenditures can act as a guide to spatial variation in demand estimates and service standards, and as a proxy for willingness and ability to pay both initial connection costs and tariffs. Another way to integrate poverty mapping data into the analysis is to use it as a means to estimate needed subsidies, provisions such as "life line tariffs," or other policies that can help the poor benefit from electrification.

As indicated in the inception report, SEL/EI team has worked to integrate the outputs received (in mid-March, 2015) from the Oxford Poverty Mapping effort funded by the World Bank for the whole country of Nigeria.[15] A map illustrating the overall results of poverty estimates for specific areas of the KEDCO coverage area is shown in in Figure 10 below. The percentages show in this map indicate the fraction of households consuming 600 kWh per year as is assumed for poor households versus the non-poor rate of 1,200 kWh per year. Details of this analysis are provided in *Annex B2 Poverty mapping and household demand estimates.*

Endnotes

1. Java Open Street Maps (JOSM) is a free, open-source desktop editing program supporting multi-user mapping tasks (https://josm.openstreetmap.de/).
2. These results include all data available as of early July, 2015, which KEDCO assures is complete.

Figure 10 **Poverty rate (% of poor households) for the KEDCO service area based on geospatial data recent research from Oxford University (Gething & Molini)**



3. Population projections for 2011 are provided by the National Population Commission of Nigeria; these were projected to 2015.
4. Total attendance at this training was approximately 40. In addition to 4 KEDCO staff who assisted in as trainers, the training was attended by teams, typically of 4 staff members, from each of the following DISCOs: Abuja, Benin, Eko, Ibadan, Ikeja, Jos, Port Harcourt, and Yola. A full list of all Nigerian DISCOs is available at http://www.nercng.org/index.php/myto-2/discos.
5. The SEL/EI team has permission from INEC to use updated data from 2015, however this dataset is only partially available: location data has been obtained, but as of June, 2015, numerous efforts to acquire data for the number of registered voters per polling unit in 2015 have not been successful.
6. National Population Commission of Nigeria projected forward based on state level growth rates.
7. "Night Lights" refers to various datasets provided by the Earth Observation Group, NOAA National Geophysical Data Center (http://ngdc.noaa.gov/eog/) which provide geo-located data for light observed by orbiting satellites, providing a useful indicator of areas with nighttime human activity, including urbanized areas.
8. http://www.nigeriaelectricityprivatisation.com/
9. Technical factors limit the total length of wire that low voltage power can travel and still be of usable quality. Although 1.0 km is widely viewed as a good technical standard, this is frequently exceeded by contractors, utilities and communities who must balance concern for the quality of power delivered against strong pressure to connect as many

customers as possible. For this report, the maximum distance of 1.5 km was chosen by KEDCO management (May 2015). Although the standard value for Nigerian utilities is typically 1.0 km, in practice 1.5 km was seen as a more realistic of the way connections are performed in practice.

10. This estimate agrees roughly with figures provided by KEDCO staff in discussions, May 2015.
11. This analysis models solar home systems as the off-grid option which can be planned reliably and generally throughout the study area with available data. However, other generation technologies can be substituted for solar by local planners where reliable, geo-spatially specific information is available.
12. Requests were made for customer billing record in an attempt to validate this demand range at the local level, but these data are not available as KEDCO is in the early stages of establishing a customer database.
13. All parameters are obtained from KEDCO, unless otherwise noted. A few critical parameters, such as cost per meter of MV and LV line, were also discussed with Transmission Company of Nigeria World Bank Project Management Unit (TCN PMU) for validation.
14. International spot market prices are available online (http://www.solarserver.com), to which 20% was added for transport and local markup. These costs were checked with the Ministry of Power and a major local vendor M-Rald Global Resources (http://m-rald.com/), and compared against recent market research and procurement efforts in other countries where SEL/EI team has worked (Uganda, Tanzania, Guinea and Myanmar).
15. Gething, P., Molini, V. (2015, June 10) Developing an Updated Poverty Map for Nigeria. Final Report. [No web address available]

CHAPTER 2

Cost and Technical Results

The preceding steps have assigned communities within the KEDCO service area into three broad geo-spatial categories: communities that are already connected or in range of grid electrification, communities that require either extension of the MV line or off-grid power for the whole community, and isolated households. Considering only this last category, SEL performs a least cost analysis to recommend an electricity system type—grid, off-grid or mini-grid—and a recommended electricity network. (The least-cost planning approach is described in greater detail in Annex E.) The following section describes the results, with details geo-spatial, cost and technical details for each of these grid and off-grid programs and components.

2.1 Overview: Grid Extension Program

As described in *1.3. Components of a Universal Electrification Program*, the majority of the universal electrification program will, *over the long term*, be achieved by adding connections and extensions to the electricity grid. Table 8 below provides a cost overview of the proposed ~$3.3 billion grid extension program.

Table 8 below divides the grid electrification program into four components, each with different costs per household connection. Since households in component A are already connected, the main concern for this component is the cost of adding meters to the 63% of customers who lack them, at accost of ~$160/household, $40 mn overall). Component B refers to the effort by KEDCO to turn "consumers" into "customers" by adding meters and establishing accounts for around 840,000 million homes (at an average cost of ~$180/HH, $150 mn overall). The next component, LV intensification, represents connections to homes that are within 1.5 km range of a transformer with low voltage line (at an average cost of ~$630/HH, $1.7 bn overall) and finally the component D, MV grid extension, in which medium voltage lines are extended to areas beyond the range of existing transformers (at an average cost of ~$840/HH, $1.5 bn overall).

The first three components of this program can be accomplished without substantial additions to the MV grid line. Due to the extensive coverage of the existing grid, these three represent nearly 70% of the entire grid electrification program and address a large portion of the KEDCO coverage area (see Figure 11 below).

Areas beyond 1.5 km from the exiting grid require extension of the medium voltage line. This component (D) constitutes about 31% of the electrification program for 2015–2030, and is shown in Figure 12 below.

The following sections explore these cost and technical results in more detail, with particular emphasis on the manner in which geo-spatial factors affect the cost buildup for household connections, leading to a prioritized grid roll-out program.

Geo-Spatial Factors in Grid Extension

The most important recommendation of the geo-spatial least-cost electrification plan is that *over the long term* grid extension is the most cost-effective means of electrifying virtually all localities (>99%). These results are shown quantitatively and visually in Table 9 and Figure 13 below.

Figure 13 below shows that the model's recommendations for non-grid systems are very rare and target areas that already have a high predicted percentage of "off-grid / isolated" households.[1]

This shows the NetworkPlanner model recommendations for electrification of settlements with grid (blue), mini-grid (red) and off-grid / SHS (green) technologies. The left panel shows an enlarged area of Katsina state already identified for

Table 8 Electricity access in 2015 and grid extension program for the KEDCO service area, 2015–2030

Electricity access status (2015)			Grid extension program (2015–2030)				
Type of access	Population[a] (Households)	Percent	Components of grid program (Type of grid access planned)	Population[a,b] (Households)	Percent	Total CAPEX (M USD)	CAPEX per HH (USD)
Grid access	7,430,000	31%	**A) Customers:** KEDCO has ~400K customers (2015); 63% need meters ($160/HH)	2,400,000 (400,000)	7%	$40	$160
	(1,240,000)		**B) Consumers:** ~840K HHs (2015 est.) consume power but do not pay KEDCO; all need meters & improved connections (~$180 per HH)	5,030,000 (840,000)	15%	$150	$180
No grid access	16,480,000	69%	**C) LV Intensification:** By 2030, ~2.7 M HHs near the grid will need LV line, meter, connection (~$630 per HH)	15,680,000 (2,670,000)	47%	$1,670	$625
	(2,750,000)		**D) MV grid extension:** By 2030 ~1.8 M more distant HHs (>1.5 km from transformer) will need MV and LV line, connection, meter (~$840 per HH)	10,560,000 (1,760,000)	31%	$1,470	$835
Total	**23,910,000** **(3,990,000)**	**100%**	**Total**	**33,670,000** **(5,670,000)**	**100%**	**$3,330**	**$590**[b]

[a] Based on census data, rural households have 6.1 persons on average vs. 5.8 for urban households. For simple computations and where the ratio of urban and rural households is unknown, 6 persons per household is assumed.
[b] It is assumed that population growth from 2015–2030 among those who currently have grid access (components A and B) will lead to net formation of new households that will need new connections requiring LV intensification (component C), MV grid extension (component D) or off-grid access.
[c] Average household costs are calculated by summing all CAPEX costs across all program components and dividing by the total number of households served.

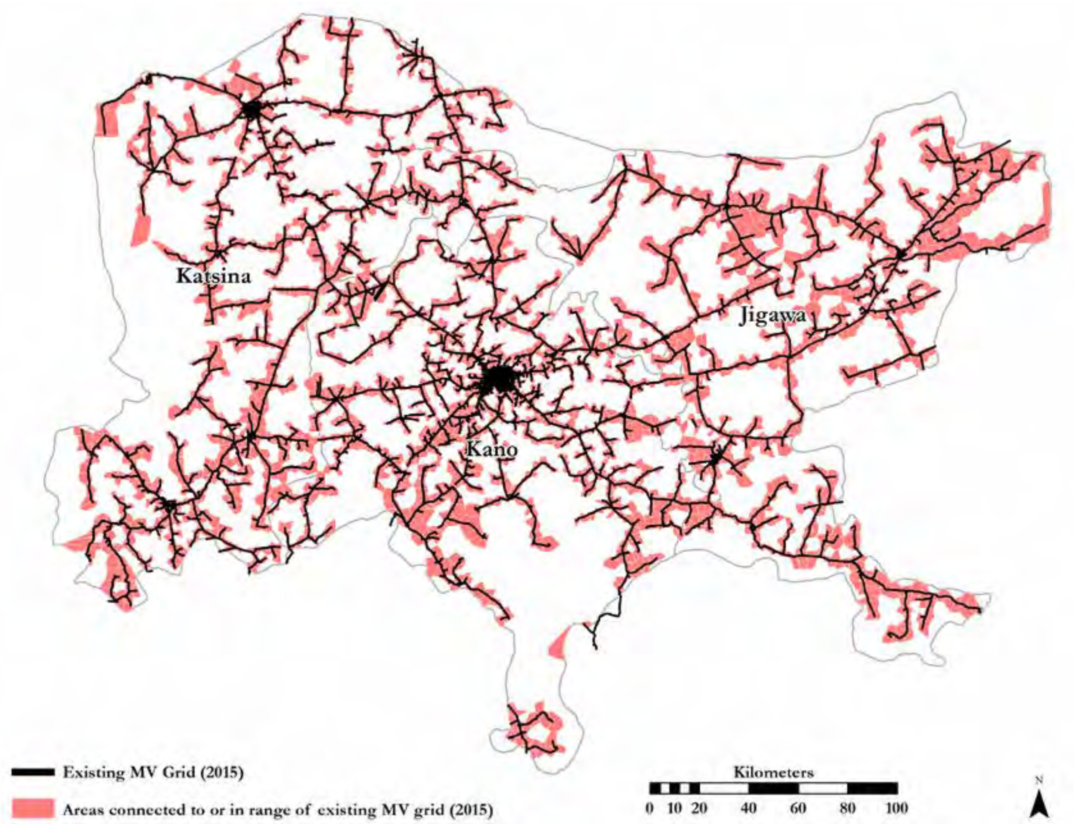
a high fraction (30%) of off-grid / isolated households (shown by the dark grey polygons) and subsequently targeted for non-grid electrification in NetworkPlanner modeling (shown by the green and red points). The right panel shows the full map of the KEDCO service area, which illustrates that non-grid recommendations are rare and confined to specific areas. The ~2,000 households targeted by NetworkPlanner for grid or mini-grid service in specific polling sites amounts to less than 2% of the ~164,000 "isolated" households previously estimated as requiring off-grid service by 2030 (see Table 3, and *Annex A2*). For this reason, we recommend that the two groups be aggregated.

A brief summary of MV grid extension costs appears in Table 10 below, for both average sized

Table 9 NetworkPlanner model recommendations for grid and off-grid (SHS) electrification in the KEDCO service area, 2015–2030

Polling sites >1.5km from transformer		Household connections recommended			
State	**Population**	**Grid**	**Mini-grid**	**Off-grid**	**Total**
Jigawa	2,410,000	512,000	—	100	512,000
Kano	2,980,000	640,000	13	60	641,000
Katsina	2,870,000	611,000	16	1,650	613,000
Grand total	8,260,000	1,763,000	29	1,810	1,766,000
Percentage	100%	>99% (99.8%)	<1% (0.002%)	<1% (0.10%)	100%

Figure 11 Areas served by improved connections and LV intensification near the existing grid connect 69% of the projected population (2030)

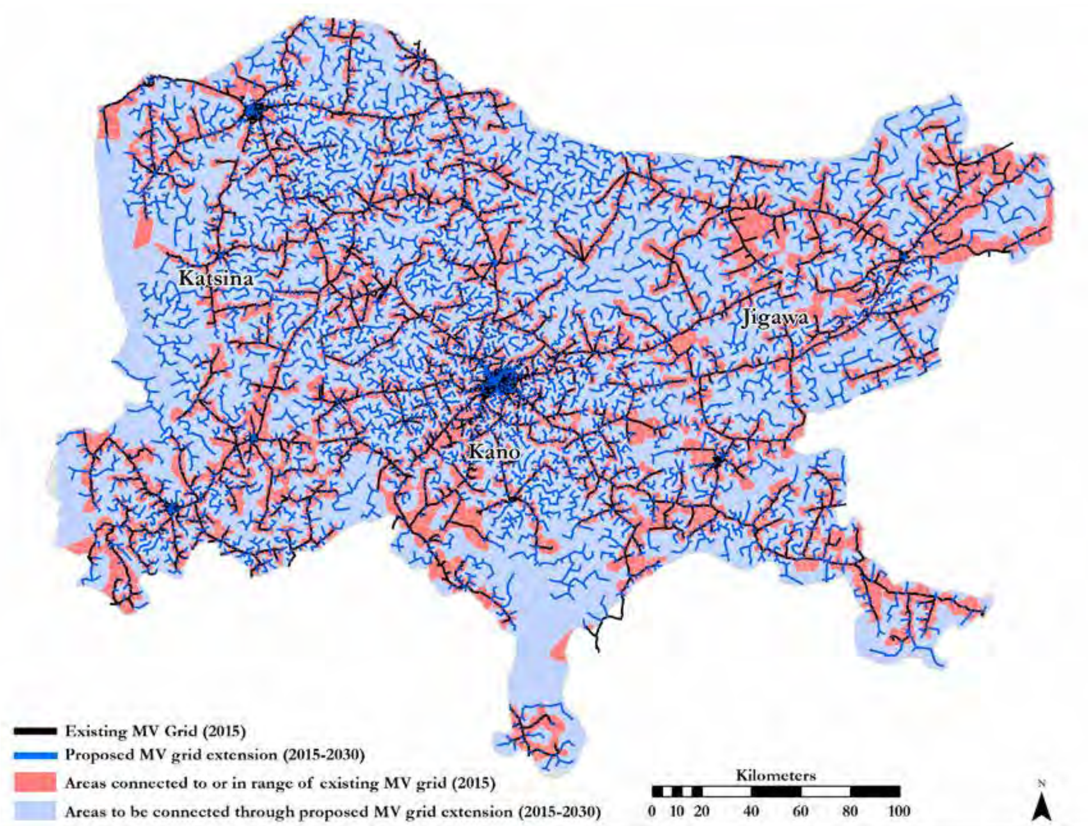


households and an "average settlement". The majority of the network expenditure for extensions, about 80%, would be for "local" costs such as low-voltage line, connection costs and transformers, while the remaining 20% would be spent on the MV network. Each of the 1.8 million newly connected homes would require about 250 W of added generation capacity, resulting in a need for around 440 MW of additional generation on the network overall by 2030. Finally, the levelized cost of electricity (LCOE) for the additions to the KEDCO system would be around 30 US cents per kWh (about

Table 10 Projected electricity demand and grid extension metrics for the KEDCO service area, 2015–2030

Indicators for MV extension program	Units	Total	Per household	Per settlement
Proposed MV line length	km	19,070	0.011	3.4
Proposed new grid HH connections	Households	1,760,000		310
Initial cost for LV grid network	USD	$1,163,000,000	$665	$204,000
Initial cost for MV grid network	USD	$308,000,000	$175	$54,000
Total Initial costs (MV + LV line and equip.)	USD	$1,471,000,000	$840	$259,000
Peak demand met (by grid)	kW	440	0.25	80
Levelized cost per kWh for grid	USD/kWh	$0.30		

Figure 12 MV extensions can bring grid access to another 27% of the projected (2030) population that is targeted for grid (with 3–4%, mostly isolated homes, for off-grid)



half of which is the US$0.16 kWh "bus-bar" cost of power, while the other half is the amortized cost of the new extensions).

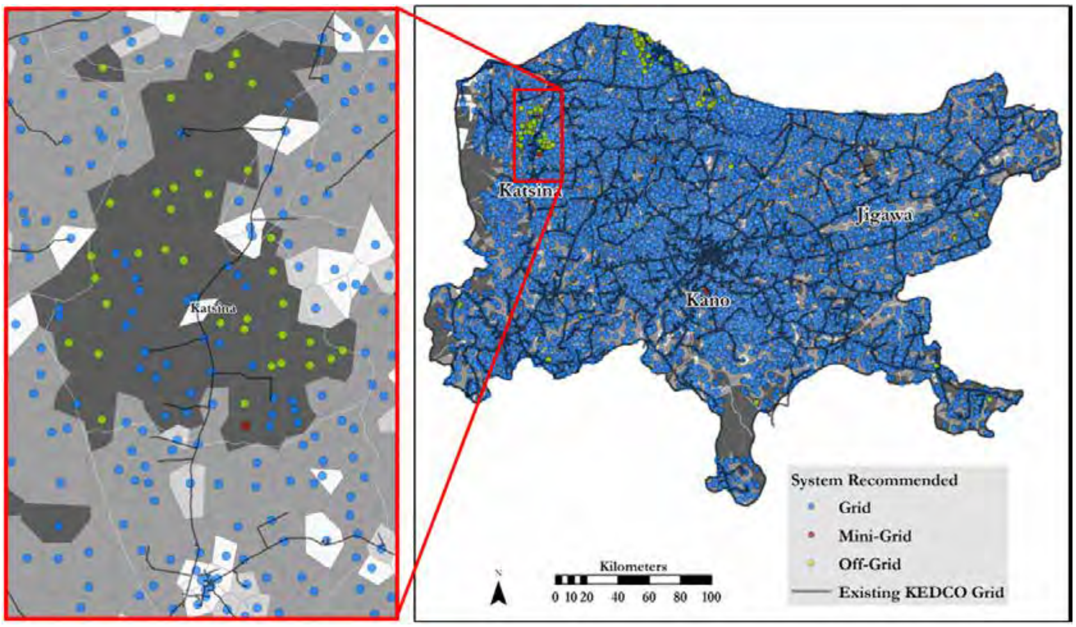
Table 11 below provides a breakdown by state of where the new grid-connected households, MV line, and new generation are recommended. The program would require nearly 20,000 km of additional MV line, effectively tripling the length of the KEDCO MV distribution network. The largest need for additional household connections and generation is focused on Kano State, but the majority of new MV grid line will be built in the more rural states of Jigawa and Katsina.

Prioritization of Grid Roll-Out

In addition to these aggregate and State-level metrics for grid extension, the SEL/EI analysis also quantifies variation in per household costs of grid extension throughout different geographic areas to allow for a prioritization of grid roll-out. In this analysis, an algorithm assigns a ranking for each grid segment which prioritizes lines that meet higher electricity demand with the shortest MV line extension. Figure 14 below shows MV grid roll-out results for the KEDCO service area—component D of the investment program—divided into four categories based on average costs per household connection.

This per household cost metric offers a means to prioritize extensions which meet a greater electricity demand per unit of investment, and thus are more cost-effective. This figure illustrates how initial phases of grid construction is more likely to reach communities that are closely spaced and nearer to the existing electricity grid, where less medium voltage line is needed per household and hence per household connection costs are lower (~$700 per connection). Later phases reach remote, rural communities where the required MV/household is much higher, resulting in higher unit costs (~$1,000 per household or more).

Figure 13 NetworkPlanner recommendations for electrification with grid (blue), mini-grid (red) and off-grid/SHS (green). Left: Enlarged portion of Katsina State. Right: Full KEDCO service area

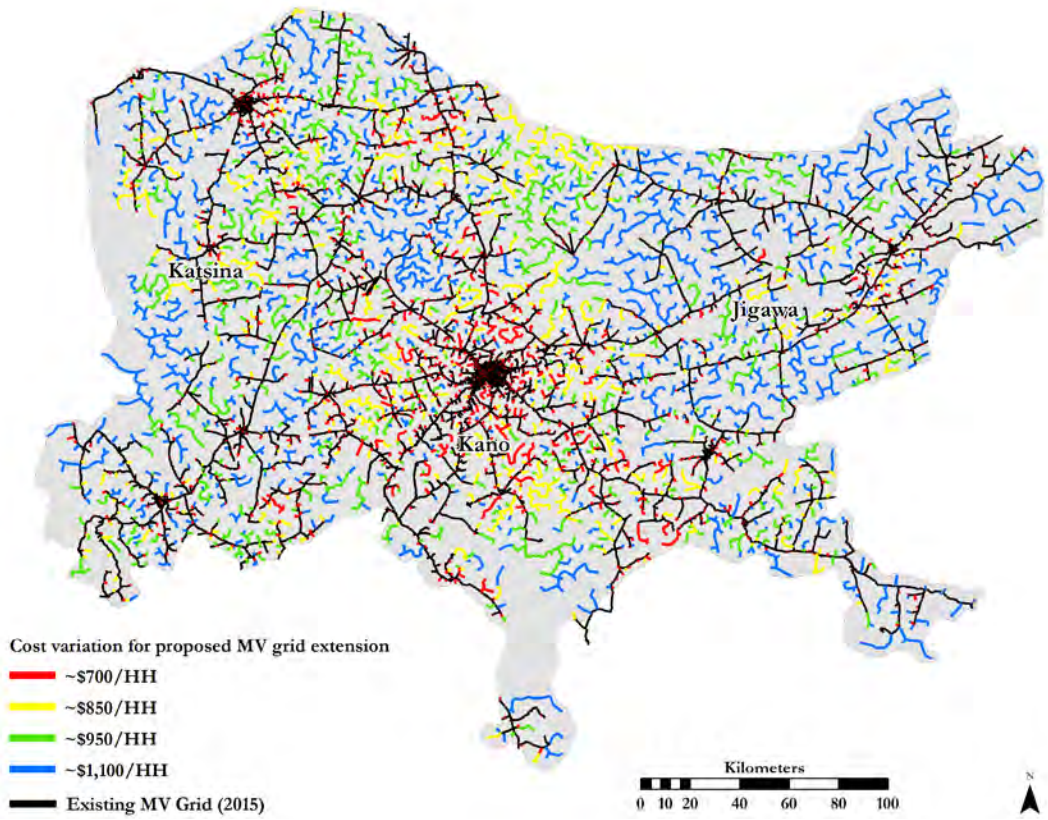


It is important to emphasize that this analysis provides a *plan* for universal electricity access from 2015–2030, not a *design* for grid construction. This applies to the grid-roll out plan, as well, in that it describes which locations should be connected, and the relative prioritization of connections, in a cost-benefit sense, and an *estimate* of overall costs and technical needs (equipment, added generation, etc.). It does not show an annual timeline for grid construction, yearly expenditures, or the specific pathways of future grid extensions, locations of transformers, etc. A more detailed design would require important additional factors, including: a) an investment plan, clarifying how quickly funds could be made

Table 11 Proposed household grid-connections with related MV line extension and new generation, for each state in the KEDCO service area, 2015–2030

State	Number household grid connections proposed		Grid Length proposed (km)				New generation needed (MW) for residential connections	
			MV grid extension			LV intensification		
	MV grid extension	LV intensification	MV	LV	MV/HH (avg, m)	LV	MV grid extension	LV intensification
Jigawa	510,000	482,400	6,600	15,200	12.9	13,200	120	120
Kano	640,000	1,523,200	5,600	18,700	8.7	34,800	170	400
Katsina	610,000	664,400	7,000	18,200	11.4	17,000	150	160
Sub-total	**1,760,000**	**2,670,000**	**19,200**	**52,100**	**10.8**	**65,000**	**440**	**680**
Grand total	**4,430,000**		**136,300**				**1,120**	

Figure 14 Prioritized grid roll-out for the KEDCO service area (2015–2030)



available, and effectively used, to construct new lines and make connections (such an investment prospectus has been commissioned by the World Bank, for which this analysis is an input); and b) input from local engineers to determine the paths of lines and best sequence of connections in response to local factors such as available electricity supply and local geography topography, right-of-way, etc. (this is anticipated as part of the implementation program to follow the investment prospectus).

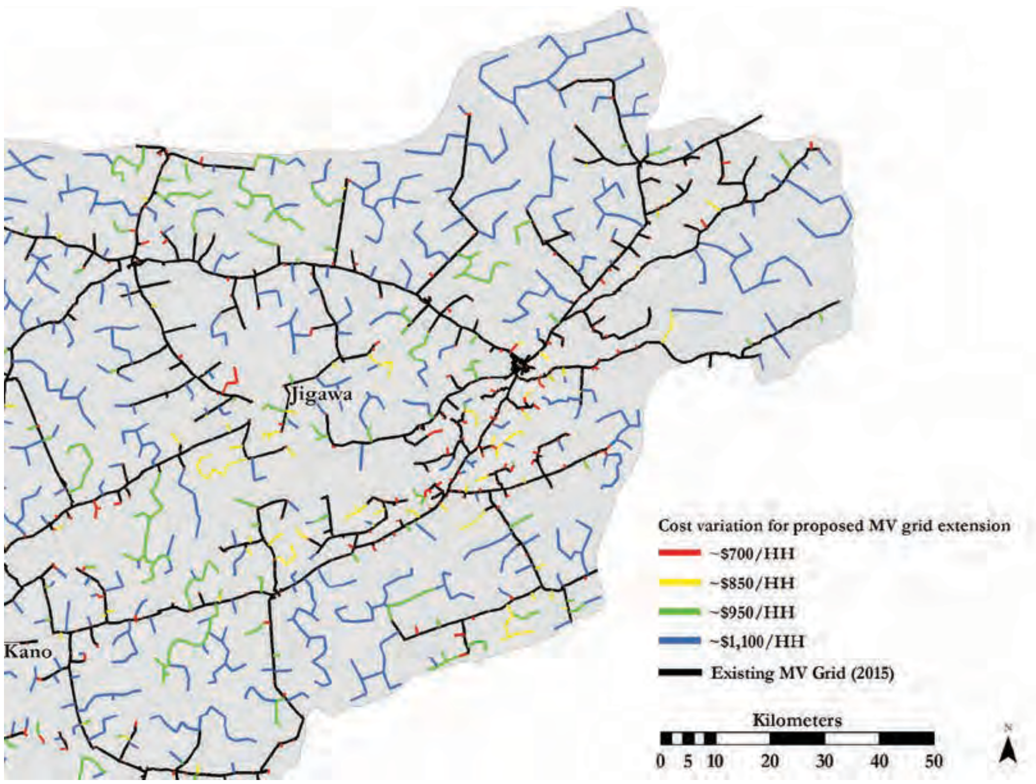
These maps are based on GIS data that can be viewed at higher levels of magnification. Figure 15 below shows the same results for an enlarged area of Jigawa State, providing a clearer illustration of how specific grid extensions can be viewed for local areas.

This figure also helps to emphasize the difference between a prioritized grid expansion plan created here, versus a true construction design. To give only one example of the sort of practical consideration that makes the two different: utilities and project implementers are likely to plan construction work at the level of the "feeder" (i.e., constructing extensions to all locations along a given line at once). However, this model's output incrementally prioritizes each connection along the line in a manner that might imply construction of some parts of a feeder in different phases. These kinds of investment and construction decisions are beyond the scope of a high-level analysis such as this. But this dataset and analysis do provide rich data to support such detailed decision-making.

From these maps, spatial patterns can be seen in the prioritization of home connections:

- High priority connections consist of in-filling in urban areas or areas close to existing grid, where a large number of new connections requiring less MV line result in a lower cost per household (~$730, on average).
- In lower priority areas, grid extension requires higher MV and LV investment per household, and thus higher costs (reaching an average of ~$1,100).

Figure 15 **Prioritization of grid roll-out in an enlarged area of the Jigawa State, 2015–2030**



Per Household Costs and Grid Prioritization

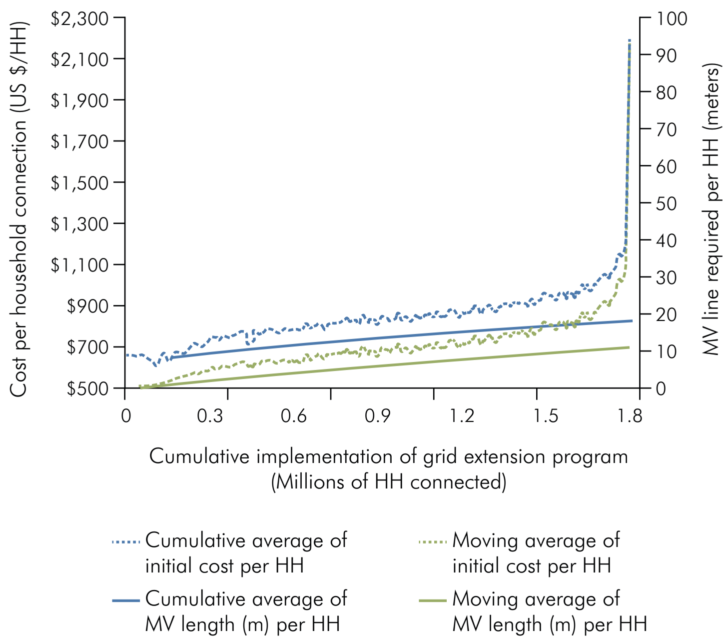
The basic cost elements of household grid connections are of two types: (i) the costs of the service drop, meter and other costs related to the connection to the home, which are approximately the same from one household to another; (ii) the costs of the LV line that spans between homes and MV extension that spans the distances between villages, both of which may vary significantly with spatial factors such as household and village density. These fixed and

Table 12 **Fixed and variable costs per household grid connection (KEDCO service area, 2015–2030)[a]**

Cost category	Notes	Low	Average	High
Connection equipment ($175)	Fixed: meter, service drop		**$175**	
Connection fee ($75)	Fixed: labor, cost to create account, fees		**$75**	
Low voltage line (at $12.6 / meter) (almost all un-electrified HHs are rural)	Varies: 15–30 meters per HH Set at 15m for urban, 30 m for rural HHs	$189	**$375**	$378
Transformer (at $100 per kVA) (varies with household demand)	Varies: 200–500 W per household Average of 350 kVA / HH	$20	**$35**	$50
Medium voltage line (at $16 / meter) (varies with village density)	Varies: 1 to 40 meters (and above) Average of 11 meters per HH	$16	**$176**	$640[b]
Total cost		$475	**$836**	$1,318[b]

[a] Based on discussions with KEDCO, April 2015. May prove less expensive due to economies of scale anticipated with large-scale procurement and implementation in a future electrification program.
[b] More than 95% of household connections can be achieved with less than 20 meters of MV line per household, setting the higher value in this table.

Figure 16 Detail of rising MV costs per household throughout the grid roll-out in the KEDCO service area, 2015–2030



variable components are presented as per-household cost build-up in Table 12 above, with notes on the low, average and high values for the latter.

The variation in per household initial costs has a small demand component, but is primarily related to geo-spatial factors, most importantly the density of households and villages over the landscape. In rural areas, households are, on average, more distant from each other, raising LV costs, and communities are also more distant from each other, raising MV costs. The cost build-up shows that these two factors are the dominant variable costs in electrification by grid extension. In very rough terms, initial costs for grid connections tend to fall within a range of ~US$700–1,100 per household which, for ~1.8 million homes, results in a total initial cost of ~$1.5 billion.

Figure 16 above provides additional detail for the medium voltage grid costs per household.

The rougher of the two red lines shows a moving average MV Length Installed per Household. This metric increases from an average of 0–5 meters of MV per household connection in the highest priority part (from a cost effectiveness prospective) of the grid extension program to 25–30 meters, for the lowest priority, most costly households (the smooth red line shows the cumulative average, which rises from nearly zero meters of MV per household to nearly 11). Similarly, the blue line shows the gradually increasing average cost per household metric, beginning at US$600–700 per household in the highest priority portion of the MV extension program, and reaching US$900–1,100 or more per household in the final phases. Note that both moving average curves show a rapid and dramatic increase in the final portion of grid extension. Here, the MV per household metric jumps quickly from around 20 meters (or about $300 worth of MV line) per household to reach 40–50 m (or about $600–800 of MV line per household). This rapidly rising helps to illustrate the tendency of grid extension to become far less cost-effective in the final stages, where a single household connection may cost $1,400 or more.[2] This may suggest alternate electrification strategies for the most remote areas, such as mini-grids or solar home systems, which could provide power instead of the grid, or for a temporary period as these locales await grid extension.

2.2 Results Overview: Off-Grid Program

It remains to assign costs to these components. The hardware costs for solar home systems vary roughly linearly with the "service standard" (assumed annual household demand, in kWh). A service standard of 150 kWh/HH-year, one-quarter of the "grid connected poor" level of 600 kWh/year described above, can be met by a solar home system of approximately 130 peak watts. Assuming a range of system sizes from 80–200 peak Watts (Wp), and an average system size of ~120 Wp, the average cost of a simple solar off-grid system would be ~$425 per household for hardware with some additional programmatic soft costs. Note that in such systems additional the costs to consumer are also include maintenance and replacement costs. Such small solar home systems would support services up to general lighting, phone charging, the use of a small television and a fan[3]. For those communities that are clustered enough, stand-alone networks (mini-grid) solutions could provide similar services. Such solar home systems do limit peak power (ranging from 100 to 200 Watts) and growth in consumption is not easily admissible. A mini-grid system where an "energy as a service" model is used allows consumers not risking maintenance/replacement costs, exploit load and consumption diversity, higher individual power limits (possibly up to 1 kW),

Table 13 Electrification status (2015) and proposed connections through both LV intensification and MV grid extension (2015–2030) for educational facilities (KEDCO service area)

Education facilities	Total	Connected to grid (2015)		Connected or w/in 1.5 km of existing grid (2015)		Connected or w/in 1.5 km of existing (2015) and proposed grid (2030)		Will need non-grid power (> 1.5 km from existing & proposed grid)	
		#	%	#	%	#	%	#	%
Total (all facilities)	**12,406**	**2,508**	**20%**	**7,946**	**64%**	**11,620**	**94%**	**786**	**6%**
Primary	10,369	1,744	17%	6,171	60%	9,599	93%	770	7%
Junior & senior	1,510	548	36%	1,309	87%	1,471	97%	39	3%
Vocational & technical	13	5	38%	10	77%	13	100%	0	0%
Unknown type	558	211	41%	456	82%	537	96%	21	4%

energy demand growth over time and easier future integration into the grid. A basic service standard of 60 kWh/HH-year per customer (with much higher consumption for small business) could be provided in the Kano service area at a cost range of $500–700, whereas a service of 120 kWh/HH-year could be provided at a cost of $1000–1200.

2.3 Electricity Access for Social Infrastructure

Considering electrification for "social infrastructure" such as schools and clinics: While these locations are certainly a vital part of any universal access plan, the overwhelming majority of these sites will be covered by the grid extension program modeled to meet residential needs. Geo-located social infrastructure data collected for the Nigeria MDG Information System (NMIS)[4] indicate that, as of 2015, only about 20% of institutions are connected, although 80% of the most important ones, such as hospitals, already have grid connections to the existing network. For those that are not already connected, 94% of all education facilities (11,620 of 12,442) (see Table 13 above) and 94% of all health facilities (3,490 of 3,693) (see Table 14 below) will fall within 1.5 km of MV grid lines proposed to meet residential needs.

Similarly, Figures 19 and 20 illustrate that the vast majority (94%) of both types of facilities will

Table 14 Electrification status (2015) and proposed connections through both LV intensification and MV grid extension (2015–2030) for health facilities (KEDCO service area)

Health facilities	Total	Connected to grid (2015)		Connected or w/in 1.5 km of existing grid (2015)		Connected or w/in 1.5 km of existing (2015) and proposed grid (2030)		Will need non-grid power (> 1.5 km from existing & proposed grid)	
		#	%	#	%	#	%	#	%
Total number (all facilities)	**3,699**	**842**	**23%**	**2,021**	**55%**	**3,490**	**94%**	**209**	**6%**
Hospital	140	96	69%	133	95%	139	99%	1	1%
Dispensary	330	21	6%	116	35%	300	91%	30	9%
Clinic, basic/primary health centre	1,428	498	35%	931	65%	1,369	96%	59	4%
Health post	1,775	224	13%	828	47%	1,659	93%	116	7%
Unknown facility type	26	3	12%	13	50%	23	88%	3	12%

Figure 17 Social infrastructure (education and health) facilities with grid access (2015)

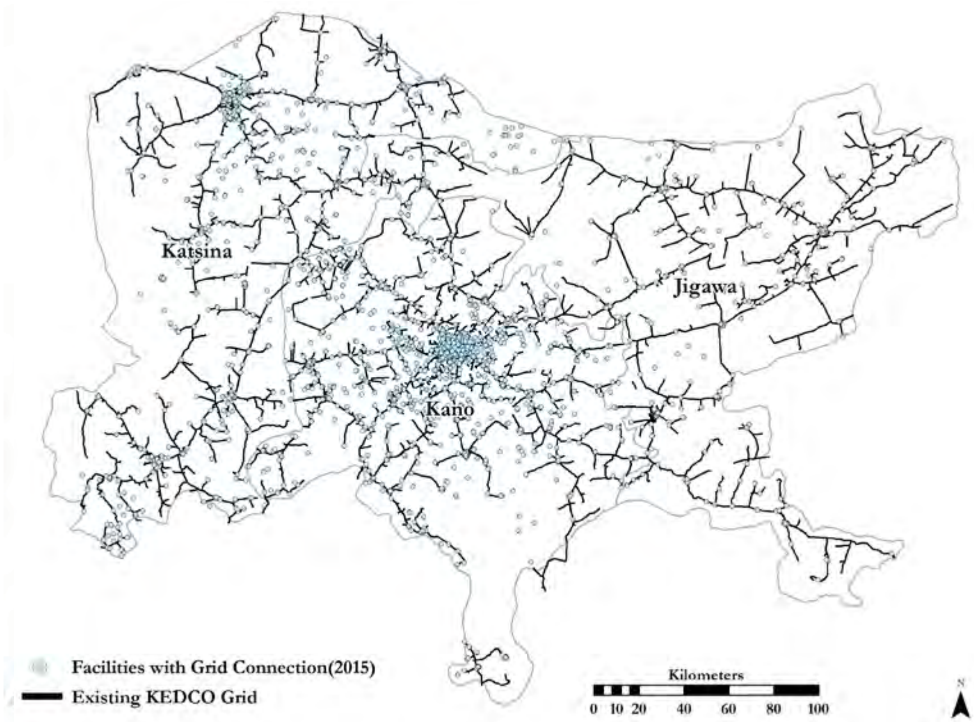


Figure 18 Social Infrastructure (education and health) facilities without grid access (2015)

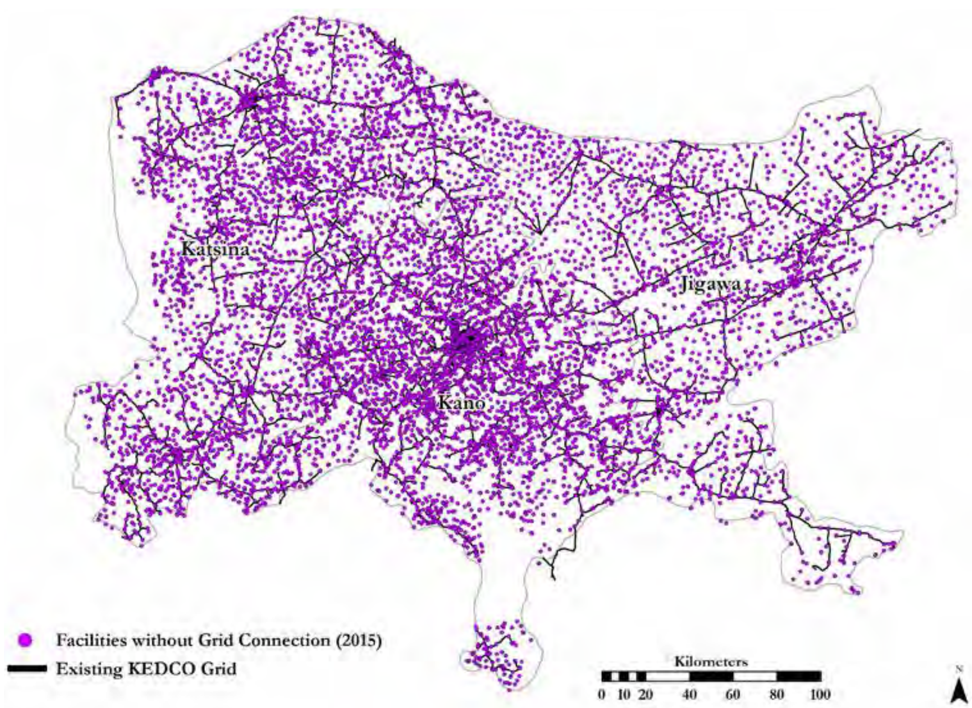


Figure 19 Social infrastructure (education and health) facilities planned for grid connection (2015–2030)

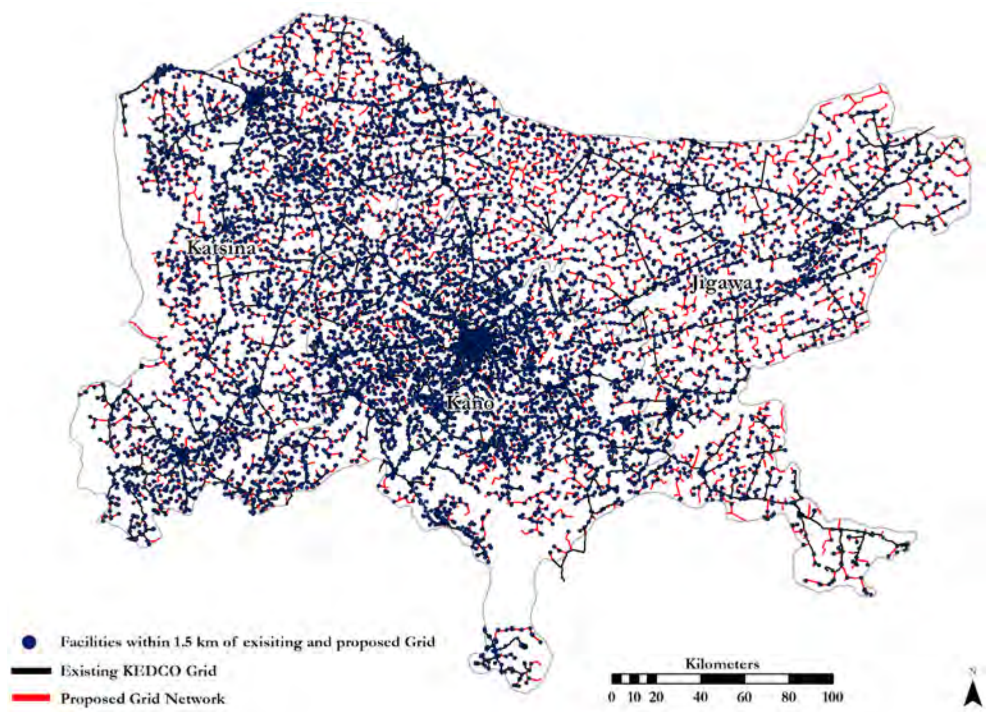
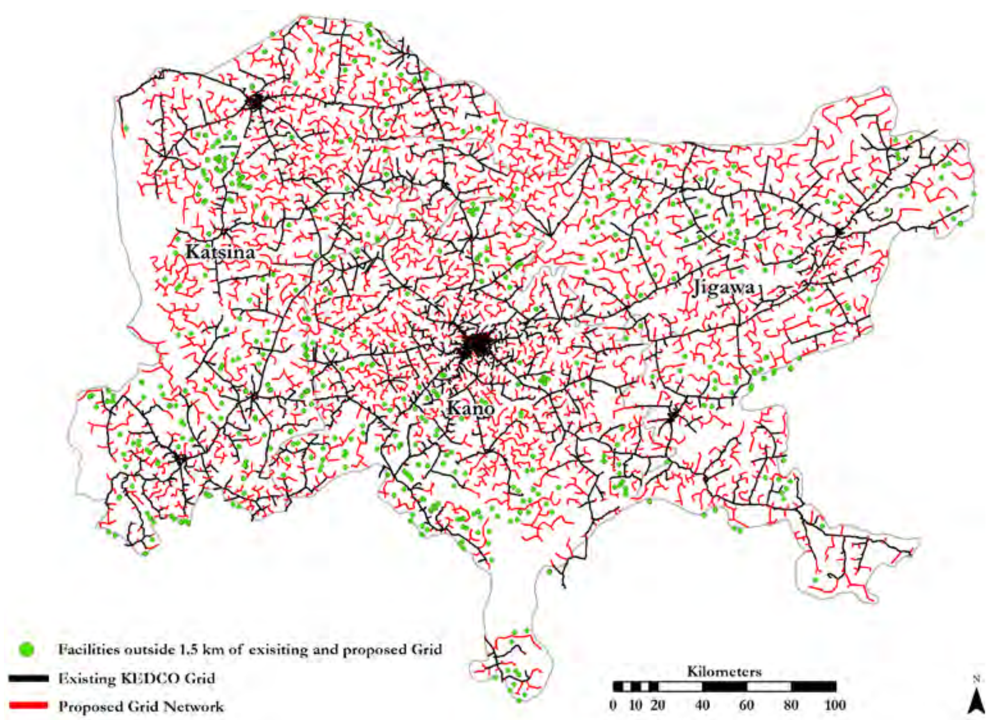


Figure 20 Social infrastructure (education and health facilities) beyond the 1.5 km range of grid (2015–2030)



get grid access during the 2015–2030 grid roll-out, while very few will remain out of range, requiring off-grid systems.

The remaining sites to be electrified by non-grid options amount to 203 health facilities and 822 schools, a total of ~1,000 facilities. These consist almost entirely of those institutions with the smallest electricity demands (small health posts and primary schools). Overall, electrification of these points would add far less than 1% to the grid extension program of more than 1.7 million households.

Endnotes

1. See discussions of "off-grid / isolated" households in "Corrections and Estimates Related to Polling Place Data" within Chapter 1.2.
2. This is a rough figure, obtained by adding the non-MV costs (about $660 per household, see Table 12 with the costs of MV line in very sparse areas ($16 per meter x ~45 meters = $720) for a total of $1,380 (rounded to $1,400).
3. These services are defined by the Multi-Tier Framework for electricity Access developed by the Bank under the Sustainable Energy for All (SE4All) engagement. The framework defines five different tiers of access and the household supply described above corresponds to Tier 2. For more information, visit: https://www.esmap.org/node/55526.
4. The Nigeria MDG Information System is an online portal providing location and attribute data for social infrastructure collected nationally in two rounds (2010 and 2014) led by the Office of the Senior Special Assistant to the President on the Millennium Development Goals (OSSAP-MDGs) for the purpose of ensuring "informed decision making and implementation in local, state and federal interventions aimed at achieving the MDGs." (nmis.mdgs.gov.ng).

CHAPTER 3

Conclusions and Next Steps

Given the data available for this analysis, the extent of the existing grid network, and the predicted demand levels for households, results have shown that grid extension is ultimately the most cost-effective solution for the 15 year electrification program modeled for the KEDCO service area. At an estimated cost ranging between $700 and $1,100 per household, the grid can be extended to reach the vast majority of those currently without service, in the process adding ~20,000 km of MV line, roughly tripling the length of the current KEDCO MV network once the MV Correction Factor is incorporated into grid extension plans. These conclusions comes with some important caveats. There may be small remote population clusters that are not captured in the demographic data, medium-voltage grid costs per household values inevitably require a significant degree of estimation, and finally the low-voltage wire needs and energy demand estimates may end up being spatially and temporally different from those assumed.

A separate analysis has addressed the problem of estimating how to meet the needs of the small remaining fraction of the population who will not cost-effectively be served by grid in the short term. It was concluded that about 3–4% of projected unelectrified population, or about 140,000 households, may be best served by off-grid technologies, solar home systems in particular. Depending upon the household density of a polling unit coverage area, it is estimated that between about 5% and 30% of rural households fall into this category, with the highest percentage applying to the most rural, sparsely populated areas. This off-grid analysis relied fundamentally upon estimates derived from visual inspection of high resolution satellite imagery, as there is currently no comprehensive rural settlement dataset for KEDCO's service area. The total cost of such a program will vary linearly with the assumed service standard, in kWh of electricity delivered per year, for each household system. Assuming a standard of ~150 kWh per year, it is likely that this program will cost ~$400–450 per household, or a total of between $55 and 60 million. As yet, there is also currently no clear consensus on the specifics of an off-grid electrification plan for this region—whether this will be led by the public or private sector, at what costs, etc.—so this analysis provided information on system sizing, cost and an overall estimate of the magnitude of the need which might help inform a discussion of such a program among policymakers and other stakeholders.

The results presented here for the NEAP-TA are based on the best available data at this time. Additional data—perhaps updated polling place data for 2015 (provided by INEC), improved data from KEDCO itself regarding existing "customers" vs. "consumers", or improved census data with greater accuracy or spatial specificity for populated places—could all help to form an increasingly comprehensive and accurate foundation of data from which to revise this analysis in the future.

Annex A – Pre-processing of Electricity Demand Point Data

A1. Derivation of Population Based on Registered Voters at Polling Units

Nigeria's 2006 Population and Housing Census reports a total national population of 140 million, with 73 million adults (over 18), of which 62 million (85%), are registered to vote. This yields a national ratio of voters to total population of about 2.25 suggesting that simply multiplying the number of voters at any polling site by this multiple provides a reasonable estimate of the total population residing near that site. While this very simple conversion offers a useful basis for a preliminary estimate, the SEL/EI team chose a more geo-spatially specific approach: census values at the LGA (Local Government Area) level were projected from 2006 to 2011, then proportionally allocated among polling units within an LGA according to the percent of an LGA's total registered voters represented by each polling unit. There were also data gaps in the original INEC data—some polling site records had location information, but no data for number of registered voters. In those cases, information from 'night lights" satellite imagery was used to identify urban and rural areas and polling units, then the average value of registered voters for polling units in urban or rural areas in each state was assigned to each polling unit that lacked a registered voter value.

A2. Estimating the Frequency of "Isolated"/ Off-grid Households

One important caveat regarding use of the INEC polling unit dataset to represent human settlements is that rural villages, particularly the smallest ones, are often not served by a polling unit located within the village. Instead, their voters are likely to be registered at polling units either in nearby villages or other central locations, such as a school that is shared by multiple settlements. This is understandable given the cost and logistics of providing polling places to the smallest and most rural communities. However, this concentration of voters for multiple villages at a single polling site results in an apparent aggregation of rural populations that risks introducing inaccuracy in geo-spatial planning. To address this inaccuracy, the SEL/EI team performed a detailed manual analysis of satellite imagery, combined with measurements to identify "isolated" households. This work began by using GIS to create polygons (yellow lines in Figure 21 below) around each polling unit (yellow point) to represent areas from which a polling site is assumed to draw its voters.

For each polling unit area polygon, SEL/EI calculated the density (voters or population per square kilometer). In addition, SEL/EI visually identified all human dwellings (blue points), calculated each point's nearest neighbor, and categorized any point more than 100 meters away from any neighbor as "isolated" (distances > 100m are red lines). The number of isolated dwellings in a polling unit area, compared with the total number of dwellings, gives a percent of isolated homes for the area. In Figure 21 above, 6 isolated dwellings, compared with 90–100 dwellings in the entire area, yields a ratio of about 6–7%. The population in this polling unit is relatively closely aggregated; in many rural polling units, 30% or more of the households appear to be "isolated" (greater than 100 meters from any neighbor).

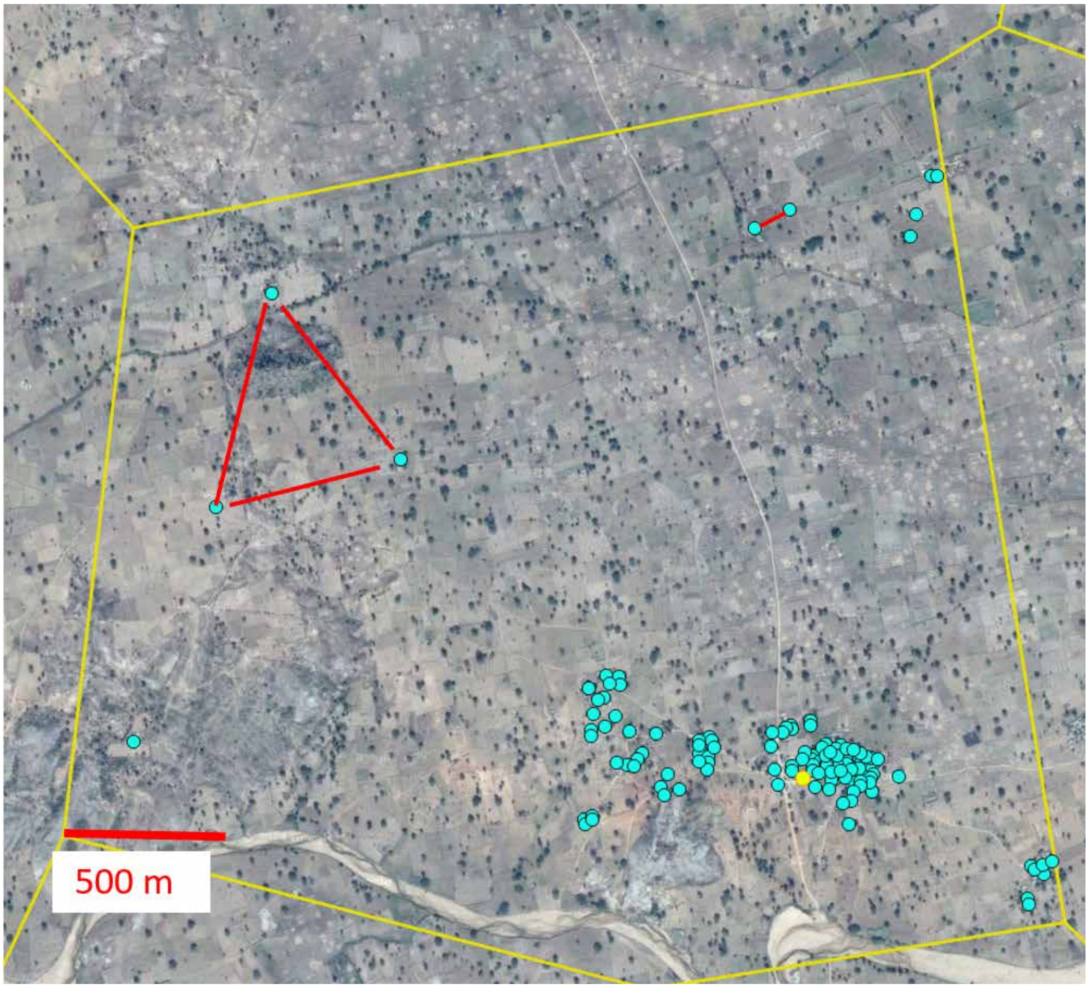
SEL/EI then repeated this process of visually identifying human dwellings in satellite imagery throughout a sample of about 95 polling units (from a total of 16, 300) chosen randomly from three different rural areas in Kano State (see Figure 22 below). For each "polling unit area" within the sample, two metrics were calculated: a) the ratio of isolated compounds and b) the polling unit's household density.

SEL/EI created plots of the percent of isolated dwellings (>100m from any neighbor) versus household density of each polling unit (see Figure 23 below). These curves allow a rough estimate of the percent of isolated (more cost-effectively served by non-grid technologies) dwellings based on a polling unit's household density. In this way, the quantitative insight gained from the visually inspected polling unit areas could then be applied to

Table 15 Estimated percentage of isolated dwellings in polling unit areas based on household density

Clustered PU density bins (HH no/sq. km)	Isolated HH ratio
0–10	30%
10–50	10%
50–70	5%
> = 70	0%

Figure 21 **Dwellings (blue) identified in satellite imagery; red lines indicate inter-household distances greater than 100 meters (yellow points represent polling places; yellow polygons illustrate estimated "coverage areas" for polling places)**



polling unit areas elsewhere throughout the rest of the KEDCO service area, using household density as the key metric.

This allowed an estimate of the percentage of each polling unit's population that is "isolated" and thus appropriate for off-grid / solar home system electrification throughout the KEDCO service area. This percentage of the population was removed from the grid extension analysis, and set aside for off-grid electrification. The final estimate is that 2–3% of total households in the KEDCO area, corresponding to 5–6% percent of currently non-electrified locations, will be most cost-effectively served by solar home systems.

A3. Estimating the "Medium Voltage Correction Factor"

As stated in the report's main body, use of INEC polling place data introduces inaccuracy in the MV line length arising from the fact that not all human settlements include polling units. The fact that many substantial villages lack a polling site can cause the model results to under-estimate the required length of MV line to connect all locations in the dataset that are grid recommended. To remedy this, SEL/EI utilized the same visually identified dwelling dataset described previously (see *A2 Estimating the Frequency of "Isolated"/Off-grid Households*). A clustering algorithm was used to identify clusters of

Figure 22 **Rural area of Kano state where visual identification of dwellings (blue points) in satellite imagery was repeated for many polling unit areas (yellow polygons)**

homes that were not represented in the polling unit data, and quantifying the additional length of MV line needed to reach them.

The effort included three broad stages:

1. This clustered dataset was run in NetworkPlanner under the same assumptions as the original dataset, which included only polling sites as populated places. As with the "isolated household" analysis described previously in Annex A2, this MV "correction factor" analysis was carried out for many polling unit polygons. The results of the two NetworkPlanner model scenarios—one using household points obtained from satellite imagery then algorithmically clustered, and the other using polling unit points—are presented in Figure 24 below.
2. The results form two curves, both showing the estimated length of MV line needed to connect households in each polling unit (y-axis) compared with the household density for each polling unit (x-axis). The higher curve (in blue) shows an estimate of the MV line length needed to connect all households that were visually identified in satellite imagery and algorithmically clustered to form proxy villages. The lower curve (in red) shows an estimate of the MV line needed to connect households using the much more limited

INEC polling place dataset. Both curves trend downward from left to right, indicating that less medium voltage line is needed per household as the density of a polling area increases. **The vertical difference between the two curves is, very approximately, a factor of two, meaning that identification of households and villages by satellite imagery leads to a greater estimated number of electrification sites spread over a greater area, meaning that roughly twice as much MV is required to complete electrification than is suggested by the INEC polling sites alone.**

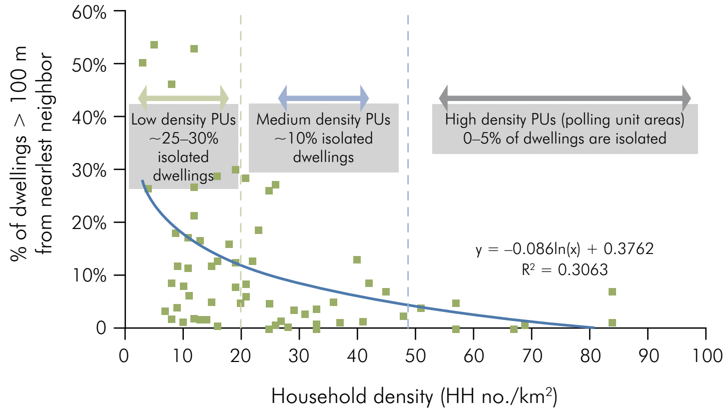
3. The cost implications of this correction factor are significant, but do not dramatically affect the total cost of the grid extension program overall. MV extension without the 2 X "MV correction factor" are about $740 per household, or $260 million total; while costs for MV extension with the 2X "MV correction factor", which are about $840 per household, or $300 million total. The application of this correction factor adds only 10–20% to the total cost for MV extension. This can be explained both by the relatively low cost of MV per km quoted by KEDCO (around US$16,000), the somewhat high initial connection costs (~US$650 per household); and the relatively extensive grid penetration, which leads to relatively short needed MV extensions per household (5–11 meters per household on average, depending upon whether one includes the doubling factor).

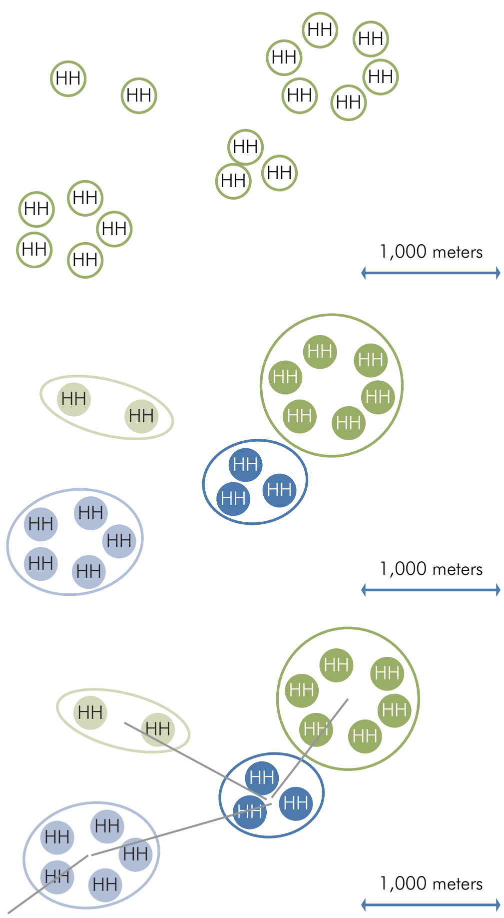
A4. Estimating Grid Penetration

The SEL/EI analysis used the following process for estimating grid penetration for the 2011 dataset:

- KEDCO mapped key grid assets, including all distribution transformers—those which step down power from MV (11/33 kV) to LV (415 V) (see Figure 2).
- INEC 2011 Polling Unit data was used to create geo-located estimates of population (see Figure 4 and *Annex A1 Derivation of Population based on Registered Voters at Polling Units).*
- GIS buffering (a standard proximity analysis which creates a circular zone around a point feature based on the radius) identified all polling units within 1.5 km of existing transformers. These Polling Unit locations were also designated as urban or rural based on "night lights" data (see Figure 6). Using a 1.5 km radius, this a total of about 13 million people, or ~55–60% of the

Figure 23 The correlation between household density and percent of isolated dwellings identified using satellite imagery in ~90 polling units belonging to the KEDCO service area



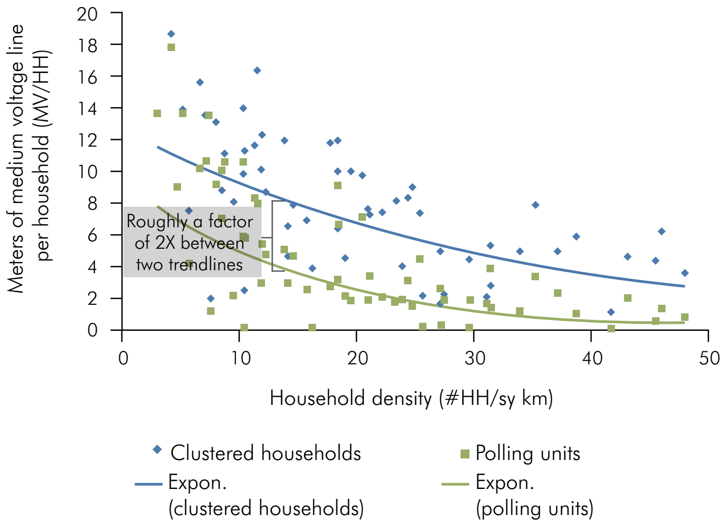


1. Household dwelling points were identified in satellite imagery for areas where polling units do not fully represent all villages.

2. These dwelling points were algorithmically clustered into groups of households within 500 meters of each other—creating a proxy for villages (colored circles).

3. The NetworkPlanner model was run, with each group acting a node for a grid connection, yielding new MV extensions not previously measured (blue lines).

Figure 24 **Two trend-lines show the relationship between MV per household recommended by NetworkPlanner and polling unit density for two datasets: clustered household locations identified from satellite imagery and locations of polling sites. Comparison of these trendlines yields a rough estimate of the difference to be approximately a factor of 2**



total area population was identified as "within LV range of a transformer". These 13 million people represent the first three components, A-C, in Table 4.

- LSMS household survey data (2011) provides percentages of households connected to PHCN service (Power Holding Company of Nigeria, the precursor to KEDCO): 80% of households in urban areas report a grid connection, while 53% of survey respondents in rural areas report a grid connection.
- SEL/EI applied these grid access rates—urban (80%) and rural (53%)—to INEC Polling Units according to the urban / rural classification based on "night lights" data. The result is ~38% of the population has grid access (either as customers or consumers), which compares favourably with the LSMS figure that around 33% of the population overall has grid access in the KEDCO service area.
- The difference between the population that is "within range of a transformer" and the population that already has grid access is about 22% of the total population. This is the population identified for "intensification" (requiring only low voltage line and connection costs, i.e. component D in Table 4).
- These already connected households (customers or consumers) and those amenable to "intensification" (LV only) were separated from the total population of the KEDCO service area, leaving the remainder (~40%) as the population to be electrified either by grid extension (MV + LV) or off-grid / solar home systems (see Annex *A2 Estimating the Frequency of "Isolated"/Off-grid Households*). These are represented in components D and E in Table 4.
- All figures were projected forward to 2030 within the NetworkPlanner scenarios that employed state level urban and rural growth rates for each point. They were also interpolated for 2015, as needed.

Annex B – Model Parameters

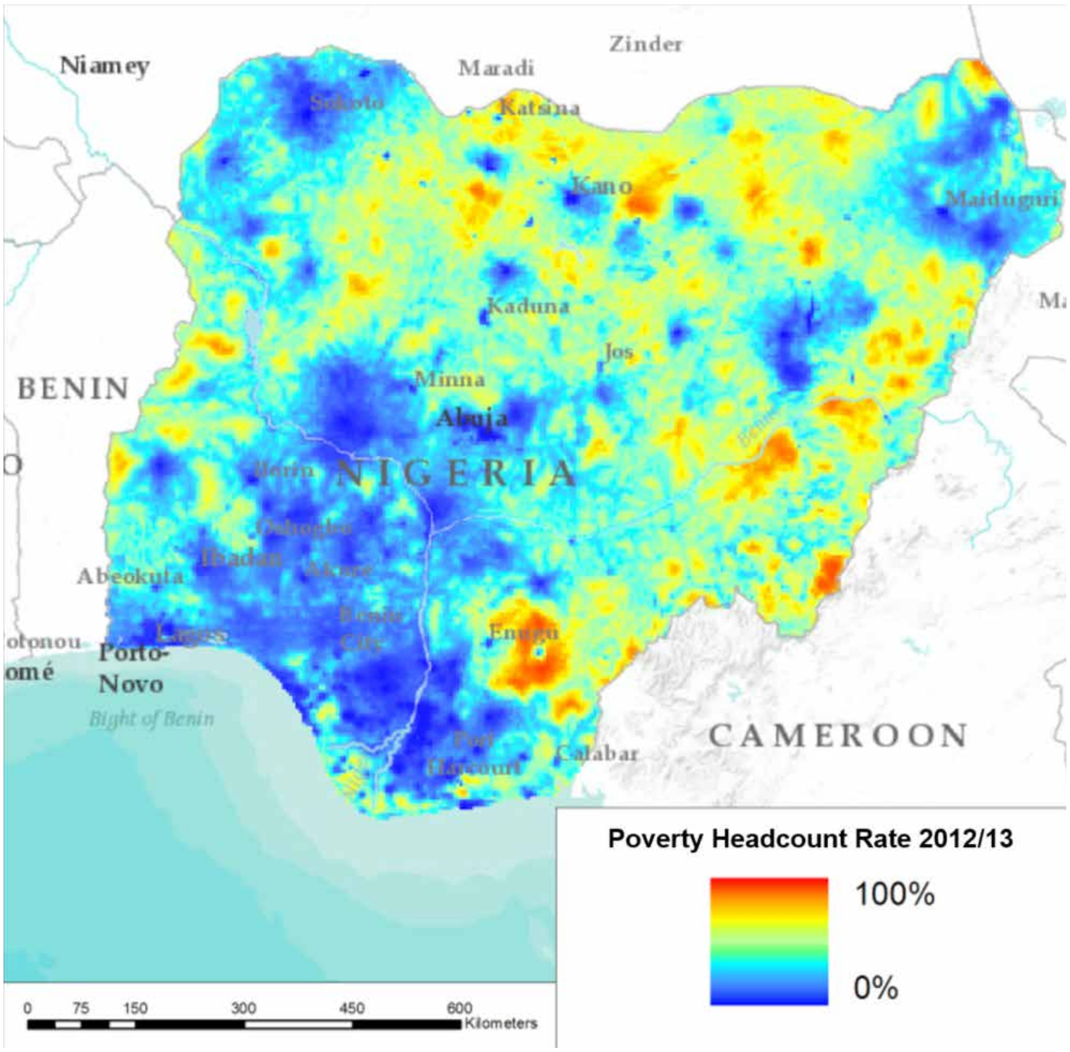
B1 List of model parameters		
Parameter category	**Parameter**	**Value used for model**
demand (household)	household unit demand per household per year	Assigned to each location based on Oxford / WB poverty mapping (see Annex B2)
demand (household)	target household penetration rate	1[4]
demand (peak)	peak demand as fraction of nodal demand occurring during peak hours (rural)	0.4[4]
demand (peak)	peak demand as fraction of nodal demand occurring during peak hours (urban)	0.4[4]
demand (peak)	peak electrical hours of operation per year	1460[4]
demographics	mean household size (rural)	6.1[3]
demographics	mean household size (urban)	5.8[3]
demographics	mean inter-household distance	Assigned to each location: 15 m in urban areas, 30 m in rural areas[1]
demographics	population count	Assigned to each location using polling unit and census data (see Annex A1)
demographics	population growth rate per year (rural)	0.00798[3] (census value recomputed to reconcile 20 year electrification time horizon with 30 year time horizon for scenario)
demographics	population growth rate per year (urban)	0.02847[3] (census value recomputed to reconcile 20 year population growth time horizon with 30 year time horizon for accounting amortization and recurring costs)
demographics	urban population threshold	urban and rural areas were identified by nightlights data, not population threshold
distribution	low voltage line cost per meter	12.6[1]
distribution	low voltage line equipment cost per connection	175[1]
distribution	low voltage line equipment operations and maintenance cost as fraction of equipment cost	0.01[1]
distribution	low voltage line lifetime	30[1]
distribution	low voltage line operations and maintenance cost per year as fraction of line cost	0.01[1]
Finance	interest rate per year	0.07[4]
Finance	time horizon	30[5]
system (grid)	available system capacities (transformer)	25.0 kVA (minimum)[1]
system (grid)	distribution loss	0.15[1]
system (grid)	electricity cost per kilowatt-hour	0.16[1]
system (grid)	installation cost per connection	75[1]
system (grid)	medium voltage line cost per meter	This was doubled to mimic the 2X MV Correction Factor (see Annex A3)
system (grid)	medium voltage line lifetime	30[1]
system (grid)	medium voltage line operations and maintenance cost per year as fraction of line cost	0.01[1]

(continued)

B1 List of model parameters		
Parameter category	**Parameter**	**Value used for model**
system (grid)	transformer cost per grid system kilowatt	100[1]
system (grid)	transformer lifetime	10[1]
system (grid)	transformer operations and maintenance cost per year as fraction of transformer cost	0.03[1]
system (mini-grid)	available system capacities (diesel generator)	6.0 kVA (minimum)[4]
system (mini-grid)	diesel fuel cost per liter	0.87[1]
system (mini-grid)	diesel fuel liters consumed per kilowatt-hour	0.5[4]
system (mini-grid)	diesel generator cost per diesel system kilowatt	150[1]
system (mini-grid)	diesel generator hours of operation per year (minimum)	1460[4]
system (mini-grid)	diesel generator installation cost as fraction of generator cost	0.25[4]
system (mini-grid)	diesel generator lifetime	5[4]
system (mini-grid)	diesel generator operations and maintenance cost per year as fraction of generator cost	0.01[1]
system (mini-grid)	distribution loss	0.1[4]
system (off-grid)	available system capacities (diesel generator)	6.0 kVA (minimum)[4]
system (off-grid)	available system capacities (photovoltaic panel)	0.05 kWp (minimum)[4]
system (off-grid)	diesel generator hours of operation per year (minimum)	1460[4]
system (off-grid)	peak sun hours per year	1320
system (off-grid)	photovoltaic balance cost as fraction of panel cost	0.5[4]
system (off-grid)	photovoltaic balance lifetime	10[4]
system (off-grid)	photovoltaic battery cost per kilowatt-hour	150[2]
system (off-grid)	photovoltaic battery kilowatt-hours per photovoltaic component kilowatt	6[4]
system (off-grid)	photovoltaic battery lifetime	3[4]
system (off-grid)	photovoltaic component efficiency loss	0.1[4]
system (off-grid)	photovoltaic component operations and maintenance cost per year as fraction of component cost	0.05[4]
system (off-grid)	photovoltaic panel cost per photovoltaic component kilowatt	800[2]
system (off-grid)	photovoltaic panel lifetime	20[4]
	Minimum node count per sub-network	20[4]

Sources:
[1] KEDCO.
[2] Market Research & Int'l Comparison.
[3] Nigerian Population Census.
[4] default value (based on international experience).
Others are noted explicitly.
[5] Modeling used the base values provided by NBS/CBN/NCC Social-Economic Survey on Nigeria, 2010, modified to fit two timelines: a timeline of ~20 years to project population from 2011 to 2030, and a timeline of 30 years since as a widely accepted duration for amortization of loans and computing recurring costs for major infrastructure investments (such as grid lines, generation equipment, etc.).
Note: parameters that were not used (null values entered) in this modeling work were removed from this list).

Figure 25 **Predicted map of poverty headcount rates in Nigeria in 2012/13. The continuous surface is the posterior mean prediction at 5x5 km resolution**



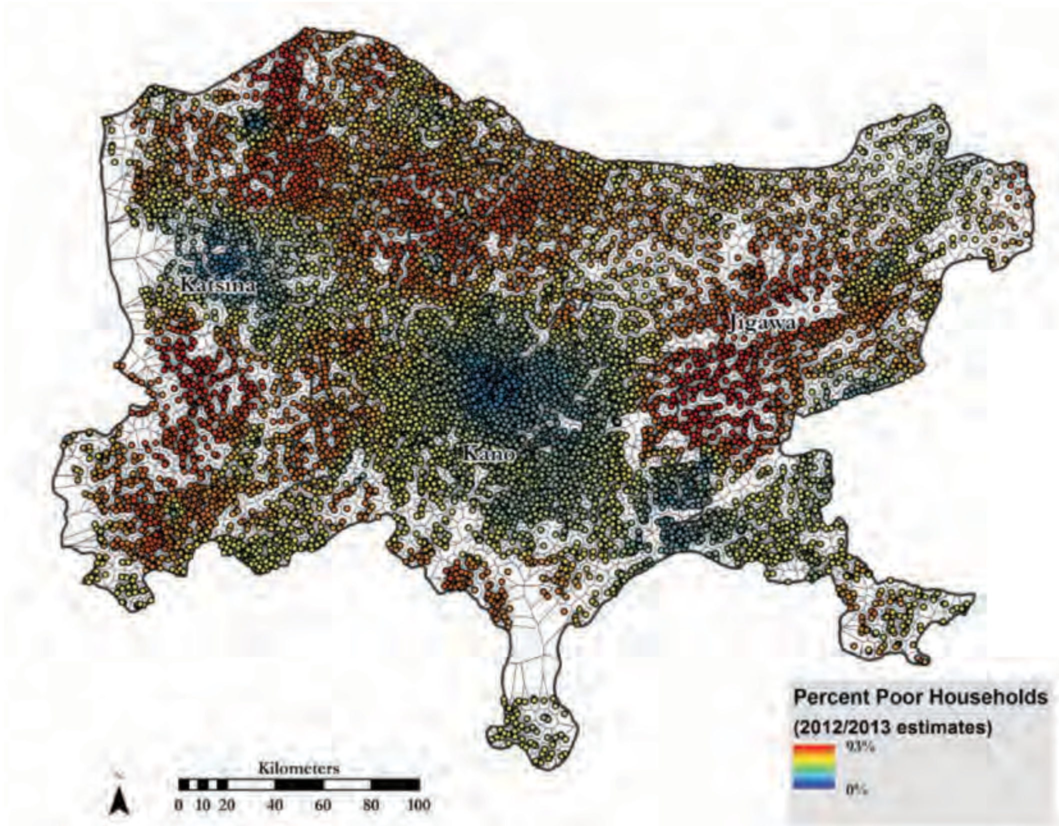
B2. Poverty Mapping and Household Demand Estimates

The Oxford Poverty Study[1] was based on General Household Survey panel survey (GHS-Panel), part of the Living Standards Measurement Surveys (LSMS) Integrated Surveys on Agriculture project conducted jointly by the World Bank and Nigerian National Bureau of Statistics. Enumeration Areas (EA) were first classified as either poor or non-poor according to the $2/day equivalent poverty lines, with all individuals within each household assigned the same classification. EA-level headcount rates were then derived as the proportion of individuals within each EA classified as poor. A geo-statistical modeling combined with Bayesian inference was then implemented using geospatial covariate layers that are correlated with the poverty headcount rate, and that partially explain variation in order to generate approximations of the distributions of the poverty headcounts at each location on a regular 5×5 km spatial grid across Nigeria.

The covariates that were chosen by the Oxford team were based on factors that have previously been shown to correlate with poverty and included in the model for testing as possible explanatory covariates. These are as follows:

- **Travel Times:** a gridded surface estimating accessibility, measured in likely travel times (via all transport methods), to cities with greater than

Figure 26 Polling unit locations in the KEDCO service area shown with poverty values extracted from the raster pixels



50,000 inhabitants. This provides a useful composite measure of the extent to which regions are rural versus urban as well as the degree of their connectedness to the national system of transportation.

- **Population Density**: gridded data on population density across Nigeria constructed from satellite-derived settlement maps and available census data.
- **Aridity and Potential Evapotranspiration (PET):** these grids allow differentiation of areas with adequate rainfall and moisture regimes to sustain agriculture versus those where drier and more arid conditions prevail.
- **Nightlights:** these surfaces allow differentiation of regions based on both the density of population and the degree of electrification of dwellings, commercial and industrial premises, and infrastructure.
- **Elevation:** a Digital elevation model (DEM) differentiating high from low altitude regions.
- **Climatic/Environmental conditions**: NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) generates high-resolution satellite imagery on three key measures on environmental conditions: land surface temperature (LST), the enhanced vegetation index (EVI) and middle infrared reflectance (MIR).

SEL/EI team then worked with the predicted pixel-level map of the poverty headcount rate for Nigeria (see Figure 25 above) at 5x5 km which was used to derive the poverty rate for each polling unit. A raster-based GIS analysis extracted values of each pixel which geographically coincides with the location of the polling units. The results of this analysis are shown in Figure 26 above. When applied to entire polling unit areas, the result is the map shown in Figure 10, of this report.

SEL/EI also calculated the daily electricity expenditure based on a detailed examination of the LSMS survey results for the three states served by

KEDCO. Energy expenditures related to services such as lighting, mobile phone, media (TV, radio, etc.)—but excluding cooking—were aggregated for poor vs. non-poor respondents. The ratio of the expenditures for poor and non-poor categories were compared and estimated to be at a factor of 2. This ratio was then used to estimate electricity demand range in the NetworkPlanner modeling for the KEDCO area: poor household demand was estimated to be 600kWh/year and non-poor to be twice as much which is 1200 kWh/year. Electricity demand was estimated for each polling unit based on poverty rate as computed above by calculating number of households—poor vs. non-poor—in each polling unit, then computing a weighted household demand. A polling unit composed of 100% poor households would have an average demand of 600 kWh/year (the lowest extreme), while a polling unit composed of 100% non-poor households would have a demand of 1,200 kWh/year. However, as shown by the preceding figures, each area has a mix of poor and non-poor households. Thus, each polling unit falls somewhere within this range, and the average household demand, across the entire dataset, is estimated to be about 840–850 kWh per year.

The demand computation in detail:

1. Apply poverty rate (from Oxford study) to calculate the *poor population* and *non-poor population* in each polling unit:

   Poor pop = *Total pop* × *Poverty Rate*
   Non poor pop = *Total pop* × (1 − *Poverty Rate*)

2. Assume the pre-electrified population is non-poor and isolated population is poor. Define *Input poor population*:

   a. If *Poor pop* − *isolated pop* ≥ *Total input pop*, which means all the input population are poor, so

      Input poor pop = *Total input pop*.

   b. If 0 < *Poor pop* − *isolated pop* < *Total input pop*, which means part of the total input pop is poor, so

      Input poor pop = *Total input pop* − *isolated pop*.

   c. If *Poor pop* − *isolated pop* ≤ 0, which means all the input pop is non poor, so

      Input poor pop = 0

3. Define *Input non-poor population*:

   Input non poor pop = *Total input pop* − *Input poor pop*

4. Assume poor household uses 600 kWh electricity per year, non-poor household uses 1200 kWh per year and household size is 6. Define *annual household electricity demand* in each polling unit:

   Input poor household = *Input poor pop/6*

   Input non poor household = *Input non poor pop/6*

   Annual household electricity demand

$$= \frac{\textit{Input non poor household x 1200 + Input poor household x 600}}{\textit{Input non poor household + Input poor household}}$$

Annex C – Sensitivity Test – Variation in Household Demand

Household demand is typically the most critical metric (whether as an assumption or modeling parameter) on the final outcome of modeling and electrification planning. This is because it fundamentally impacts the relative cost-effectiveness of various technologies with very different balances of initial and recurring costs. One of the most important factors that electricity demand impacts is the recommended proportion of grid and non-grid electrification technologies. Grid electrification typically has relatively high initial costs (for wire, transformers, connections) but lower recurring costs (since the "bus-bar" cost of power tends to be as low as possible). In contrast, solar photovoltaic systems tend to have lower initial costs since but has relatively high recurring costs (due to the need to continually reinvest in battery storage). Mini-grids typically offer an intermediate option to meet demands that are too high to be met cost-effectively served with solar home systems, but not large enough to justify connection to the full grid. Changes between the proportion of grid and non-grid systems, in turn, impact another key metric for electricity system planning: the medium voltage line required per households

Because the type of system recommended by the model is most sensitive to variation in household demand, SEL/EI has included a brief analysis of this sensitivity. Table 16 below shows how changing household demand influences electricity system recommendations and MV/HH for the third component of the electrification plan for the KEDCO service area, involving households beyond 1.5 km from existing transformers.

For base demand scenario, the household electricity demand per year per household is in a range of 600–1200 kWh, depending on the poverty rate, with an average of about 840–850 kWh/year. While the model results show shifts in the recommendation of grid, mini-grid or off-grid / solar home system electrification technologies as demand changes, these changes even at their maximum, amount to an extremely small percentage of the electrification program overall. The largest variation, an increase in recommended off-grid household systems from ~2,000 to ~12,000 due to 50% cut in household demand from the base value, yields less than 1% change in the overall mix of technologies. Thus, as a source of uncertainty in the overall results, household demand has a far smaller impact than other important, and currently irresolvable, sources of uncertainty. The latter include the uncertainty in population values (at least 10%, as a conservative estimate, though no data source exists for validation) and MV line lengths (approximately a factor of 2, see Annex A3) caused by the necessarily reliance on INEC polling unit points as a proxy for populated place data from a source such as a detailed, village level census (which is not available for Nigeria). Moreover, these changes are also quite small compared with the 140,000 off-grid systems recommended following the identification of isolated homes by satellite imagery. The changes in mini-grid recommendations are even smaller, given that the total number of systems is recommended for a maximum of 174 households, representing less than 0.01% of the overall electrification program. Considered in the comparison to the electrification program as a whole, these variations are insignificant in a practical sense, since they are all well within the margin of error of an analysis such as this one.

Table 16 Variation in recommended electricity type and MV/HH with changing household electricity demand

Household electricity demand		Households recommended for each electrification technology			MV length/ HH (m)[a]
kWh per HH per year (average, all households)	Percent of "base" demand	Grid	Mini-grid	Off-grid	
853	**100% (Base)**	1,763,385	29	1,809	10.96
426	**50%**	1,752,625	—	12,598	10.76
640	**75%**	1,762,051	—	3,172	10.90
1706	**200%**	1,765,049	174	—	11.10
2,559	**300%**	1,765,183	40	—	11.12

[a] These results have been adjusted to reflect the 2X "MV Correction Factor".

These results—obtained by large variation of the most critical parameter in the modeling system—show that the overall recommendation of grid as the dominant system type are quite robust on a cost and geo-spatial basis. While off-grid systems may have a significant role to play in the electrification of more remote and isolated households within the KEDCO service area, the INEC data used for this requires additional processing and assumption, along the lines of the procedure explained in Annex A2, to yield quantitatively significant guidance.

Annex D – Least-Cost Electrification Modeling

A key tool used in this planning approach is **NetworkPlanner**, the Sustainable Engineering Lab's (SEL) web-based geospatial electricity cost modeling and planning software.[2] The tool allows users to explore cost tradeoffs of different electricity technologies and create quantitatively rigorous costs and technical estimates for electricity planning. Application of the NetworkPlanner tool and approach typically includes three broad stages of work.

Step 1: Data Gathering and Preparation

The electricity planning effort begins with gathering and preparation of relevant geospatial, cost, demographic and economic data in collaboration with government, utilities, and other key practitioners and stakeholders. This includes geo-referenced population figures, data representing both the planned and existing electricity grid, and detailed costs of electricity inputs and equipment. These data serve as the basis for computation of the fixed and ongoing costs for the grid and off-grid systems. NetworkPlanner also draws upon other data types which may or may not have a spatial dimension but are essential for forecasting, the most important being electricity access rates, population growth rates, geographic information on urban versus rural areas, poverty and wealth data, and electricity demand values, particularly for the residential sector, which is typically the most important for questions of electricity access in under-served areas. The specific data gathering steps taken for this analysis are described previously in Chapter 1 – Input Data and Parameters

Step 2: Least-cost Electricity Grid and Off-grid Planning

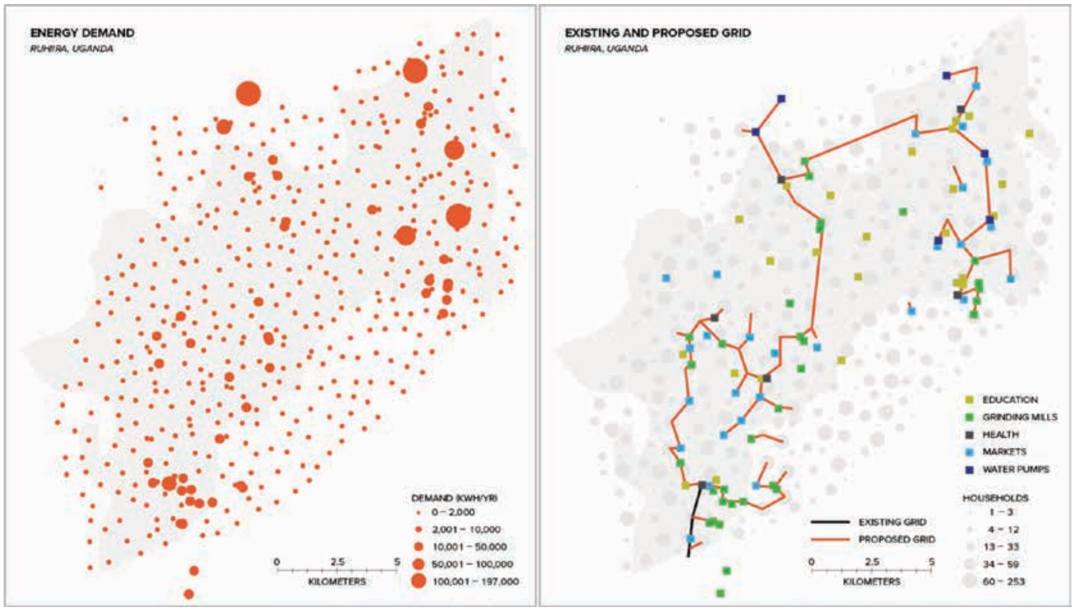
Drawing upon the information obtained in the first step, the model then applies a range of user-defined parameters to project population, demand growth, and costs for power equipment independently for every point in the proposed system. It then performs a least-cost comparison of on-grid, mini-grid, and off-grid electricity systems for each settlement. The NetworkPlanner model first projects the expected population and electricity demand for each settlement, as shown by the Uganda example (Figure 27, left panel).

This is followed by a computation of technical system requirements to meet these electricity needs, as well as the fixed and recurring costs for electricity supply, for all points. Cost calculations are then made, **incorporating all initial and recurring costs over the long-term (30 years[3])** for all system types (grid, mini-grid, off-grid). The total costs (initial and recurring) for each point become the basis for the algorithmic identification of communities recommended for grid connectivity, as well as those locations for which mini-grid or off-grid (solar home system) is the least-cost option. Communities recommended for the grid are identified and the corresponding electricity network is mapped in Figure 27 (right panel). Finally, a cost-benefit analysis of all grid network segments considers the energy delivered (in kWh) compared to the total costs, and prioritizes segments that deliver more energy for lower investment. The result is a least-cost electricity plan. Locations where the grid is not recommended are instead assigned the least-cost non-grid alternative which may be mini-grid (solar, diesel, hybrid, etc.) or off-grid (typically solar photovoltaic home systems). For this analysis, these (very few) off-grid recommendations made by the NetworkPlanner software have been added to the (much larger) component of isolated households and "transitional" off-grid connections.

Key Metric: Meters of Medium-Voltage Line per Household (MV/HH)

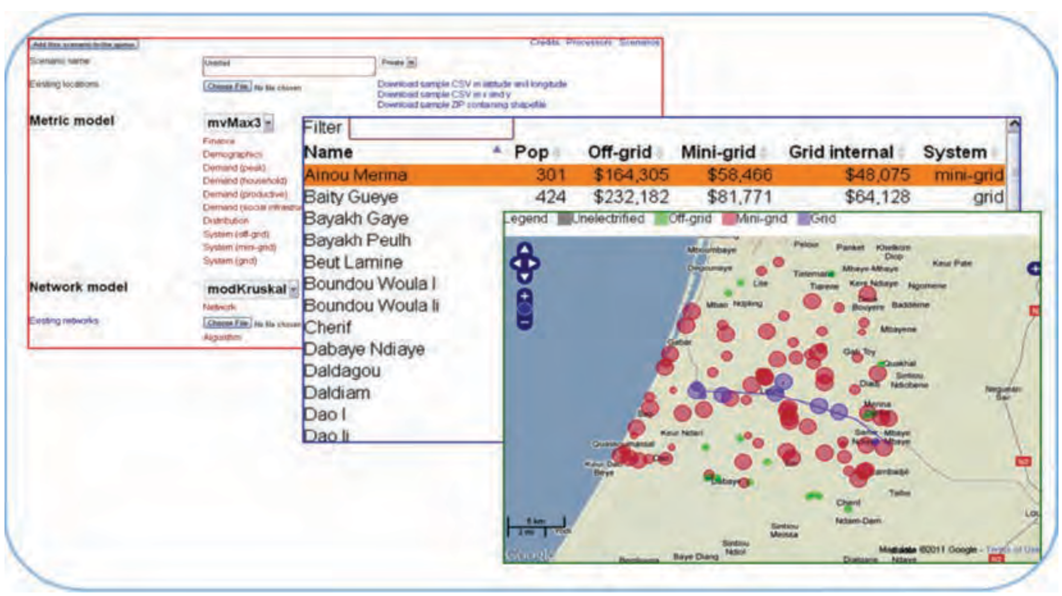
Many costs related to electric power infrastructure are either the same for all households (e.g. the cost for an electric meter) or vary with electricity demand (the costs for transformers, solar panels, or a diesel engine). A key insight from and justification for geo-spatial electrification planning is that a few important costs related to electric grid infrastructure have a spatial dimension. The most important of these is the length of medium-voltage grid line required to connect communities, which creates a substantial cost differential between costs per households in dense / urban versus sparse / rural areas. The key metric this analysis employs to reflect this geo-spatial factor is ***meters of medium voltage line installed per household connection***, or **MV/HH** for short. MV/HH is a valuable metric, first, for understanding the cost-benefit trade-offs related to grid extension versus off-grid alternatives, and, second, for prioritizing grid extensions in a least-cost manner. In general, the medium-voltage line per household (MV/HH) is low in urban and peri-urban areas, reducing grid extension costs on a per household basis, and higher in remote and rural

Figure 27 **NetworkPlanner map with magnitude of electricity demand for each point shown by circle size (left), 2030; and algorithmically specified least-cost electricity grid network (right) (example is from a rural area in southwestern Uganda)**



areas. When the metric MV/HH is used to select which communities should be reached by grid, and then to algorithmically determine the most cost-effective pattern of connections, the result is typically to concentrate connections and prioritize sequential extension within denser areas, which are lower cost, and continue onto more remote, less dense, higher cost areas.

Figure 28 **Model summaries (data and maps) presented through a web browser format**



Step 3: Data-rich Outputs

NetworkPlanner provides data-rich reporting of results that can be the basis for detailed charts and maps. First, summary data and maps are presented immediately in the web-browser, allowing users to make rapid, high level assessments of outputs to guide decisions about revisions to subsequent model runs (Figure 28 above). For more detailed results, technical and cost data are provided in tabular format (comma separated variable) while map information is provided as shapefile outputs. These formats can be processed and revised locally according to specific project objectives.

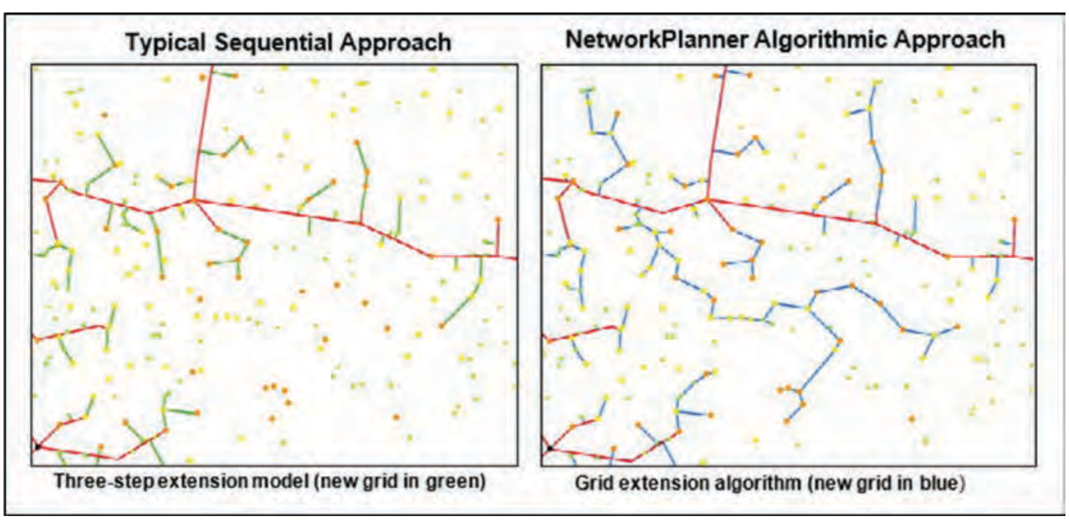
Benefits of the NetworkPlanner Approach

At a fundamental level, the analysis performed by NetworkPlanner is familiar to electrification planners and utility engineers: the software evaluates a combination of factors, including electricity demand, cost and distance from existing grid, to determine where grid extension is affordable. The key difference for a planner using the software is the size of the datasets that can be considered, and the speed and scope of the analysis. Due a combination of factors—including a lack of detailed geospatial data, or difficulty in evaluating large datasets as a whole—most grid extension plans consider only incremental or "sequential" grid extension to connect locations near the existing grid, in a manner that cost-effective in the near term based on current infrastructure. In contrast, the NetworkPlanner model considers the entire set of populated places, however far from the grid, simultaneously and over a longer time horizon. The difference in the two approaches is captured in Figure 29 below.

The typical "sequential" approach looks for connections within a limited radius (usually 10–25 km) of existing MV lines. Longer extensions to major towns and cities are typically considered on an ad hoc basis, perhaps weighing political considerations and, most importantly, annual budgetary constraints. This limits the number of cost-effective opportunities, thus leaving large areas without grid access (see Figure 29, left panel). Non-grid options, such as mini-grids or solar home systems, tend to be considered in an ad hoc fashion as well. This approach is necessarily limited in scope, and neither grid or non-grid options are likely to be considered from a quantitatively rigorous, cost-benefit perspective, across the entirety of the un-electrified population. This tends result in slow progress toward universal electrification.

In contrast, the algorithmic approach taken by NetworkPlanner considers the dataset as a whole, allowing villages to be connected to neighbors according to the most cost-effective pattern of connections over longer temporal and spatial scale. In effect the algorithm can evaluate not only where the grid is currently, but where it will expand in coming years. As a result, grid extensions typically reach further into un-electrified areas to connect larger

Figure 29 **Sequential versus algorithmic approaches to grid extension planning**



villages that are cost-effective to serve, but distant from the current grid (see Figure 29, right panel). Meanwhile, areas that are not cost-effective for grid over the long term can be identified throughout the entire dataset, allowing planning for non-grid systems comprehensively, on a large scale.

The speed of the algorithm analysis also permits multiple model runs to be compared to determine sensitivity of the results to changes in different cost inputs, assumptions, and other factors. (Results of this approach are described in Annex C – Sensitivity Test – Variation in Household Demand).

Endnotes

1. Gething, P., Molini, V. (2015, June 10) Developing an Updated Poverty Map for Nigeria. Final Report. [No web address available]
2. The system website (networkplanner.modilabs.org) offers details on the system, including sample datasets useful for training.
3. Thirty years is chosen as the duration for amortizing investments (2015–2045), not the duration of the electrification program, which is approximately 15 years (2015–2030).

PART 2

INVESTMENT PROSPECTUS FOR THE ELECTRIFICATION OF THE KEDCO SERVICE AREA (2015–2030)

Advisory Service Document

Consultant Summary Report

Contents

Figures

Tables

Abbreviations and Definitions

ATCC	Aggregate technical, commercial and collection losses
BPE	Bureau of Public Enterprise
DISCO	Distribution company
ECA	Economic Consulting Associates
EPSRA	Electric Power Sector Reform Act
FGN	Federal Government of Nigeria
IFI	International Financing Institution
KAEDCO	Kaduna Electricity Distribution Company
KEDCO	Kano Electricity Distribution Company
LGA	Local Government Area
MYTO	Multi-year tariff order
NAPTIN	National Power Training Institute of Nigeria
NBET	Nigerian Bulk Electricity Trading Company
NEAP	Nigeria Electricity Access Program
NEPA	Nigerian Electric Power Authority (former vertically integrated electricity utility)
NEPP	National Electric Power Policy (2001)
NERC	Nigeria Electricity Regulatory Commission
NESI	Nigerian Electricity Supply Industry
NGN	Nigerian Naira
NIAF	Nigeria Infrastructure Advisory Facility
NIPP	National Integrated Power Project
NW	North West
Off-grid	Electricity provided other than through the main DISCO network (i.e., isolated grids, SPDs (see below) and distributed power such as solar home systems and pico lighting)
PHCN	Power Holding Company of Nigeria (successor to NEPA)
PRG	Partial Risk Guarantee
RAB	Regulatory Asset Base
REA	Rural Electrification Agency (Federal level)
REB	Rural Electrification Board (State level)
SHS	Solar home systems
SPD	Small Power Distribution company
TCN	Transmission Company of Nigeria
WACC	Weighted Average Cost of Capital

Key Data

Exchange rate, September 2015: US$ 1 = Naira 200. Calculations were made in 2015 and starting in January 2016 the exchange rate experienced major fluctuations (as of June 2016 the official exchange rate dropped to US$ 1 = Naira 280 and the unofficial rate is still lower).

Price datum: mid-2015 (Costs are based on the prices and exchange rate of mid-2015. It is assumed that subsequent movements in the exchange rate will eventually feed through into local prices and costs and purchasing power parity will prevail.)

Financial year for Discos: 1 June to 31 May

Executive Summary

This Investment Prospectus was developed in close collaboration with the Kano Electricity Distribution Company (KEDCO) and is based on the geospatial least-cost electrification plan produced by the Earth Institute of Columbia University.

The Prospectus provides a multi-year action plan for the achievement of universal access by 2030 in the Kano service area, combined with an assessment of the projected investment needs, financing gaps, and possible sources of funding for the implementation of the first five years of the electrification rollout.

The recommendations contained in the report reflect and respond to the operating context and the challenging sector environment of KEDCO, while integrating the knowledge emerged from best practices in international experience.[1] The Prospectus identifies the key weak links, and interrelated issues, in respect of the major gaps and ambiguities in the policy, institutional, and financing frameworks that pose significant barriers to achieving universal access by 2030 at least-cost. Investments alone will not be sufficient, and these make or break challenges for scaling up access—especially those outside KEDCO's control—require priority attention and resolution.

The Prospectus is divided in seven sections. The report provides first an overview of the Kano service area and the findings of the geospatial analysis (Chapter 1) to then present the access rollout plan up to 2030, detailed scenarios for the first five years of implementation, and an overview of capacity strengthening needs (Chapter 2). The key role of sector institution and policies is highlighted (Chapter 3) before providing an assessment of the electrification plan's investment requirements and related financing gap (Chapter 4). The last two sections are devoted to equity considerations (Chapter 5) and the potential offered by off-grid solutions for the timely scale-up of electricity access (Chapter 6).

This Summary presents an overview of the main findings and recommendations emerged from the analysis.

ES1 Introduction

The Kano Electricity Distribution Company (KEDCO) service zone comprises the states of Kano, Katsina and Jigawa in the North West Nigeria, with a combined population of about 24 million and an estimated 4 million households. Today, access to electricity grid in the KEDCO service zone is approximately 31% of the population. Schools, clinics, and a large number of businesses also have limited access, not only in rural areas. By 2030, the population in the Kano service zone is projected to be of almost 34 million or about 6 million households. Under business-as-usual, the share of population without access will *grow, not diminish.*

The KEDCO's Business Plan attached to the Performance Agreement under the overall Concession Agreement submitted at privatization (2012), and entered into force in January 2015, envisages capital expenditures for a small number of "new customer" connections (about 350,000 in a five-year period). However, these in effect are already reflected in the 31% access statistic mentioned above; as they mostly represent the installing of meters in the sub-population of existing consumers without meters presently.[2]

The analysis underpinning this Report is guided by the national targets identified in the Federal Government of Nigeria (FGN)'s National Electric Power Policy (2001). Specifically, the KEDCO's electrification plan for achieving universal access by 2030, is underpinned by the following building blocks:

- **Geospatial least-cost electrification rollout program plan (2015–2030)** to achieve universal access by 2030. This high level (MV, LV, final beneficiary connections) geospatial plan also delineates broadly the boundaries in space and over time of areas for staging a well-designed and coordinated off-grid rollout across the entire KEDCO service zone for pre-electrification; particularly in areas where grid extensions are not projected to materialize through the mid-term (2025). Also identified are investments for major equipment categories, including MV extensions, LV rollout, final customer connections where grid delivery is appropriate.

- **Implementation Readiness** – A rapid appraisal was undertaken at start to broadly gauge critical readiness factors that pose material limitations for scaling up affordable and reliable electricity access, efficiently and sustainably, and in a timely manner. Some are relatively easy to address by targeted capacity strengthening (especially technical, planning, logistics of mobilisation and program management of a hugely scaled up access rollout program by KEDCO). Some others are inter-related systemic factors endemic to the sector's power market operating environment that are beyond any single sector agents' control. These are severely limiting KEDCO's financial condition and its space to undertake even routine capital expenditures critically needed to upgrade the existing network and operations. In addition, there are "show stoppers" that emanate in one manner or another, from ambiguities and key gaps in the enabling policy and regulatory framework today. *Any meaningfully significant start of implementation of an electrification programme for achieving universal access can only begin subject to the Federal Government of Nigeria's (in collaboration with the Ministry of Power and NERC) addressing of the key enabling show stoppers identified in this report*.
- **Investment Financing Prospectus (2018–2023)** – The investment financing requirements for achieving universal access are substantial and financing must be sustained over the duration of the program and beyond to 2030, and ensuring its "bankability" is the pivotal challenge. No country that has achieved universal access, or advanced substantially in access provision, has done so without significant levels of public funding support for investment sustained over the program duration; irrespective of whether the distribution sector was privatised or a national utility. The Prospectus highlights for the specific case of KEDCO the extent of the projected financing gap in magnitude, and the potential sources of funds—besides private equity—that would have to be intermediated by the Government for the KEDCO Prospectus.
- **Technical assistance and capacity strengthening for key sector institutions and agents** are identified in terms of areas of focus directly linked to and essential for the successful implementation of the programme; although detailed scoping can only be undertaken once the inter-linked set of key policy and regulatory ambiguities and gaps are effectively addressed.

ES2 Least-cost Geospatial Electrification Rollout Programme

A high level KEDCO least-cost geospatial plan for scale up of electricity access in KEDCO's entire service area was prepared by the Earth Institute of Columbia University. The analysis and results provide a geospatial and quantitative frame for the design and detailing of a well-coordinated and harmonized implementation program for off-grid electrification over a fifteen-year timeframe (2015–2030), alongside the grid rollout, which is the focus of this report.

Columbia University undertook a digital mapping of the spatial demographic settlement patterns of households across the entire service area. In addition, KEDCO engineers and field staff were trained by the Columbia geospatial specialists to undertake the digital mapping of KEDCO's existing network infrastructure (MV lines). This involved digital data capture and processing to prepare the spatial representation data layer to support the least-cost analysis of network rollout.

The Columbia University Network Planner Platform is supported by several digitised data layers (demographic, socio-economic, affordability, existing MV infrastructure). The modelling algorithm rapidly assesses the relevant technical, economic and financial trade-offs underlying the delivery modalities and technology options available—grid connections by LV intensification, MV lines extension, off grid Solar Home Systems and isolated mini-grids—to identify the least-cost option for access provision.

The geospatial analysis indicates that over the long term (2030), grid extension is the least-cost electrification option for virtually the entire population (~97%) within the KEDCO service area.

Table 1 below summarizes the components and costs for a ~US$3.3 billion[3] grid extension program that will reach about 5.3 million households, resulting in nearly universal grid coverage, by 2030:

a. **Customers**: KEDCO has approximately 400,000 residential customers who are billed, but only 160,000 are metered (63% receive estimated billings).
b. **Consumers**: About 840,000 households are served with electricity but are not metered not registered as customers, they all require meters.
c. Customers without a meter and consumers together are the lowest hanging fruit in the electrification programme as they require a one-time very low capital investment to install appropriate metering and integrate them into the customer billing and revenue collection systems; thereby boosting otherwise lost revenues from energy purchased but unbilled. From a commercial and business perspective this represents a high yield and quick payback investment opportunity.
d. **LV Intensification**: By 2030, 45% of projected homes will be situated in locations that are currently within 1.5 km[4] of an existing

Table 1 Electricity access in 2015 and grid extension programme for the KEDCO service area, 2015–2030

Electricity access status (2015)			Grid extension program (2015–2030)*				
Type of access	Population[a] (Households)	Percent	Components of grid program (Type of grid access planned)	Population[a,b] (Households)	Percent	Total CAPEX (M USD)	CAPEX per HH (USD)
Grid access	7,430,000	31%	**A) Customers:** KEDCO has ~400K customers (2015); 63% need meters ($160/HH)	2,400,000 (400,000)	7%	$40	$160
	(1,240,000)		**B) Consumers:** ~840K HHs (2015 est.) consume power but do not pay KEDCO; all need meters & improved connections (~$180 per HH)	5,030,000 (840,000)	15%	$150	$180
No grid access	16,480,000	69%	**C) LV Intensification:** By 2030, ~2.7 M HHs near the grid will need LV line, meter, connection (~$630 per HH)	15,680,000 (2,670,000)	47%	$1,670	$625
	(2,750,000)		**D) MV grid extension:** By 2030 ~1.8 M more distant HHs (>1.5 km from transformer) will need MV and LV line, connection, meter (~$840 per HH)	10,560,000 (1,760,000)	31%	$1,470	$835
Total	**23,910,000** **(3,990,000)**	**100%**	**Total**	**33,670,000** **(5,670,000)**	**100%**	**$3,330**	**$590**[c]

Source: Earth Institute, 2015.

[a] Based on census data, rural households have 6.1 persons on average vs. 5.8 for urban households. For simple computations and where the ratio of urban and rural households is unknown, 6 persons per household are assumed.

[b] It is assumed that population growth from 2015–2030 among those who currently have grid access (components A and B) will lead to net formation of new households that will need new connections requiring LV intensification (component C), MV grid extension (component D).

[c] Average household costs are calculated by summing all CAPEX costs across all program components and dividing by the total number of households served.

*Least-cost grid coverage is 97 percent.

transformer. They require possibly a simple LV extension; otherwise service drops and meters. Costumers, consumers and LV connections together target a total of nearly 4 million homes, which represents almost 70% of the universal access program.

e. **MV Grid Extension**: About 1.8 million households are located beyond 1.5 km range of a transformer and their connection would require extension of MV lines and LV reticulation. This segment corresponds to 30% of the overall grid-access programme.

Table 2 below highlights physical program specific parameters—kilometers of MV and LV lines, and incremental demand from the new connections—specific for each of the three states in the KEDCO service zone.

Physical Program – Over half the population in the KEDCO service zone is in Kano state. Significantly for the access program implementation, Kano is the most urbanized of the three states (over 50% of the LV physical program). The MV physical program numbers in Table 2 also reflect that the populations in Katsina and Jigawa states are not only less urbanized, but live in communities that are more scattered, reflected by the fact that about 70% of the MV extension is targeted for Katsina and Jigawa, and MV line needed per household is higher in Jigawa and Katsina (11–13 m) than in Kano (8–9 m).

Incremental demand – The grid extension program will result in a substantial increase in generation supply requirements for the KEDCO service zone. The program would add 5–5.5 million new residential customers to the KEDCO grid, with incremental demand of about 1,100MW,[5] of which about 700 MW is attributable to new connections spatially located near existing transformers (“intensification”).

ES3 Programme Implementation – Readiness

KEDCO (indeed, most the other DISCOs as well) is still attempting to correct years of under-investment and poor management of the industry. A Rapid Readiness Assessment was undertaken at the outset to gauge the key hurdles and challenges to the company’s ability—managerially, technically, and financially—to mobilize for another priority, of the magnitude and scope called for by the universal access program; even though scaling up access is within the broader mandate of the terms of its Concession Agreement entered into with the Federal Government of Nigeria (FGN) and the Bureau of Public Enterprises (BPE).[6]

The Readiness Assessment focused on the key factors and drivers that pose a material and significantly inhibiting impact on KEDCO’s technical, operating and financial performance in the immediate to near term; and looking beyond, to the Company’s ability and incentives as a private utility to initiate implementation of an access scale up program of the scope, and scale identified by the Geospatial least-cost roll-out plan. Broadly, the key challenges to initiate and accelerate the program implementation broadly stem from two institutional framework dimensions:

i. those within KEDCO, that are relatively easily and quickly addressable, and
ii. those critically impacting KEDCO but largely out of its control as they are driven by the external environment in the sector within the utility must function, including in particular: (a) regulatory framework and process for retail tariff review and setting; and, (b) systemic modus operandi of the bulk power supply market adequacy, cost structure, and transactional payments settling environment presently.

ES4 Mobilizing Physical Programme Implementation

KEDCO has limited experience to date of extending electricity grids on any scale. Most if not all of the “new connections” reported and/or depicted in its capital expenditure plan filed with NERC, are in essence a few new meter installations mostly.[7] Further, KEDCO presently have limited human, material and technical resources for undertaking a major programme of connecting customers through intensification and grid extension.

KEDCO staff and management acknowledge that purely from a technical and engineering standpoint, to a large extent the electrification work will need to be and can be contracted out to the private sector (both grid and off-grid). However, KEDCO will need targeted capacity building to enable it to supervise and manage a major electrification programme. Fortunately, the private sector in North West Nigeria is sufficiently experienced in undertaking electrification works, though not on the scale necessary to achieve the electrification roll-out required for KEDCO.

Table 2 Technical summary for the LV intensification and MV extension components of the universal access programme for the KEDCO service area, 2015–2030

	Number household grid connections proposed		Grid length proposed (km)				New generation needed (MW) for residential connections	
			MV grid extension			LV intensification	MV grid extension	LV intensification
State	MV grid extension	LV intensification	MV	LV	MV/HH (avg, m)	LV		
Jigawa	510,000	482,400	6,600	15,200	12.9	13,200	120	120
Kano	640,000	1,523,200	5,600	18,700	8.7	34,800	170	400
Katsina	610,000	664,400	7,000	18,200	11.4	17,000	150	160
Sub-total	**1,760,000**	**2,670,000**	**19,200**	**52,100**	**10.8**	**65,000**	**440**	**680**
Total	**4,430,000**		**136,300**				**1,120**	

Source: Earth Institute, 2015.

Upstream training and capacity strengthening can readily address this limitation in implementation capacity to the physical program rollout; both within KEDCO as well as trading of more private contractors typically provide in-house training for linesmen, fitters, jointers, etc.

In particular, the Industrial Training Fund (ITF) is used for training engineers and technicians for more complex equipment and processes. In the electricity sector, the National Power Training Institute of Nigeria (NAPTIN) operates a training facility on the outskirts of Kano city that provides training for the electricity companies in NW Nigeria. This facility is equipped with modern equipment. While it does not currently provide training in the skills needed for the expansion of the distribution network (linesmen, fitters, jointers, etc.).

ES5 Financing the Universal Access Rollout Programme

The investment requirements of the least-cost access scale up program are substantial. For the grid component, capital expenditure of about $3.3 billion over 15 years is estimated, at an annual average of $220 million per year over the program implementation period. Undertaking implementation of such a program will require mobilisation of significant levels of financing flows into KEDCO, sustained year-in-and-out over its implementation horizon; and at terms that do not undermine KEDCO's commercial and financial position.

Under the present policy and regulatory framework and review process in-place, financing the universal access implementation program is not a bankable proposition. To wit, the Readiness Assessment clearly indicates:

- The multi-year tariff order ***(MYTO) approved in February 2016 covering the next 5–10 years, does not make allowance for large scale electrification investment.*** This will need to be satisfactorily remedied before the electrification programme can be launched. Indeed, there are no explicitly mandated access targets over the medium term and beyond. Furthermore, under the current MYTO 2015 regime, tariff revenues are in-sufficient to even cover 100 per cent of all operating expenses with rapidly accumulating deficits of account payables.[8]
- The bulk power market that KEDCO purchases supply from, is still marked by conditions of power supply inadequacy (even planned allocations), considerable unpredictability, and a rising unit cost of bulk power generation, most of the time working in the direction of pushing retail tariff adjustments upwards. Under such circumstances, the lagged six monthly tariff review process of NERC, to remedy such "unanticipated changes" to assumptions in the baseline tariff calculations, results in adding to the cumulatively mounting adverse pressures on KEDCO's financial conditions.

Everything considered, for the foreseeable future, very limited equity contributions can be expected forthcoming from KEDCO owners towards financing some portion of the capex for the universal access program implementation. And as highlighted above, financing capex for the access scale up program via retail tariffs is not a workable proposition.

Indeed, relevant experience from other nations—that have effectively implemented electrification programmes for achieving universal access—unambiguously indicates that *no country has achieved universal electricity access—irrespective whether the distribution sector is privatised or in public hands—without some form of public funds (subsidy) to finance a substantial portion of the capital investment requirements of the access rollout (MV, LV and service connections),* at least in the early stages of program implementation when revenues from other sources are inadequate.

Indeed, this distinguishing feature of the enabling policy framework marks a dividing line separating those countries that have effectively navigated a universal access rollout and others that are stalled or move in starts and stops. This represents a lynchpin (and make-or-break) policy issue that the FGN/Ministry of Power would need to address in any new/updated National Energy Policy for Universal Electricity Access. The policy context for achieving universal access, goes well beyond addressing "rural electrification".

More specifically, a necessary pre-requisite for any meaningful and sustainable start of an electrification programme, is for FGN to adopt a specific policy, encompassing much more than a statement of vision, and access targets. Inter alia, the "National Universal Access Policy" should address clearly the full range of enabling policy measures and drivers necessary to facilitate the DISCOs in scaling up electricity access in a systematic and comprehensive manner for provision of adequate, affordable and reliable access to all residents. The national access policy should also clarify the key roles, mandates and accountabilities of the sector institutions (including State and Local Authorities) and stakeholders, whose engagement is essential in some manner for achieving the Universal Access Program's time-specified targets.

Such a policy would need to transparently put forth and articulate the principles and key supporting mechanisms for ensuring affordability, especially for the poor (connection charges[9] and tariffs); at the same time ensuring commercial viability of KEDCO. To the extent that NERC regulated tariffs—guided by FGN policy on access—combined with other revenue sources potentially available to a utility[10] do not allow recovery of 100 per cent of the capital expenditures (capex) of the access scale program (investment in MV, LV and final service drops and connections, meters); the universal access policy would need to identify the means and mechanisms for providing public funds to bridge the shortfall (investment financing gap associated with the access rollout implementation each year). Such funding would need to be ex-ante, administered transparently and backed by independent regulatory review, oversight, monitoring and compliance process of the physical program implementation, and by an independent and competent trust agent to administer the funds flows and reporting requirements.

ES6 Phasing Strategy for Implementation of the Electrification Programme (2016–2023)

In light of the Readiness Assessment considerations highlighted above, this section recommends a time-phased implementation (2016–2030), as shown in Table 3:

- *Phase 1 (present-2017 end) – Laying essential groundwork*
- *Phase 2 (2018–2023) – Building momentum and acceleration in scale of implementation (grid and off-grid)*
- *Phase 3 (2024–2030) – Full throttle grid electrification rollout*

Phase I allows for time essential to prepare for program launch (both on- grid and off-grid), which would require the timely undertaking of specific actions, as shown in Table 4, to set in place a policy and regulatory enabling environment and to acquire the capacity and materials needed for the programme implementation. Development partners could provide targeted support via technical assistance to strengthen the capacity ok key sector actors.

In particular, the preparatory phase should focus on three dimensions:

- ***FGN to prepare and enact National Universal Access Policy*** – to drive Nigeria's National Elec-

Table 3 Electrification phasing for the KEDCO service zone

PHASE	PERIOD
PHASE 1	**2016–17**
	Preparation *Capacity-building* – directly linked to facilitate grid rollout consistent with achievement of annual connection targets. *Finalise national policy for enabling achievement of universal electricity access* – targets, public funding support, tariffs, and guidelines on service standards appropriate for range of off-grid access services (pre-electrification, as well as remote area); Regulatory framework: update tariff regulation and related oversight consistent with national access policy; to monitor achievement of DISCO targets for access per agreed annual rollout plan parameters. *Off-Grid program:* complete detailed design of key components of rollout; including institutional framework, service standards, certification, and annual targets to be achieved consistent with overall geospatial least-cost rollout plan (2015–2030) *Tier 1 and 2 beneficiary segments*[a] – market based supply and delivery chains for cash-and-carry pico-solar PV products and home systems that are quality certified. *Isolated mini grids* (Tier 3+) – identify business models that are commercially viable, and readily scalable, consistently with meeting off-grid program targets.[b]
PHASE 2	**2018–23**
	Accelerate grid electrification carefully *Grid:* Focus on intensification with some MV extensions. Build up experience. Substantial increase in grid access by 2023. *Off-grid*: launch pre-electrification program for Tier 1 and Tier 2 beneficiary segments. For Tier 3+ field test business models and schemes for isolated micro/ mini-grid networks. For latter, focus priority on spatial locations projected to receive grid service after 2023; per geospatial least-cost plan.
PHASE 3	**2024–30**
	Full throttle grid electrification *Grid*: Focus on extension of the MV grid; complete any remaining or emerging intensification. *Off- grid*: continue with pre- electrification where appropriate.

Note: the off-grid pre-electrification programme entails both communities that are not expected to receive access in the medium-term and those that are not expected to receive a grid connection by 2030.
[a] A Multi-Tier Framework for electricity access was developed by the World Bank Group under the Sustainable Energy for All (SE4All) engagement. The framework defines five different tiers of access for electricity supply corresponding to different electricity services is further discussed in Annex 4.
[b] Various donors are providing support for off-grid electrification in Kano zone and elsewhere including GIZ and DFID.

trification Rollout Program for Universal Access as outlined above. The Policy will include access targets and supporting financing mechanisms.

- **NERC** – informed by the Universal Access Policy—to appropriately refine, expand and detail the MYTO framework and update its oversight, review and verification processes and mechanism to play its due role in support of the Universal Access Implementation Program.
- **KEDCO** – to strengthen its organisational and functional capacities to implement the access scale up program particularly in relations to planning, design, procurement, construction management, contracting, materials management, quality and standards. In parallel, KEDCO would continue to further reduce technical and commercial losses and strengthen its financial stance.

Table 4 Preparatory Phase – Key Actions

Responsible agent	Action	Milestone
On-grid electrification		
FMP	Design and adoption of a National Access Policy	by end 2016/beginning of 2017
KEDCO	Develop plan for electrification showing indicatively when different areas will be electrified. This will allow them to be prioritised for off-grid electrification.	by end 2017
FMP/NERC/KEDCO	Set electrification targets, targets developed in coordination with the NERC tariff review.	beginning early 2017
NERC/KEDCO/FMP	Update MYTO.	Begin early 2017 for implementation of new tariffs in 2018
Off-grid electrification		
NERC/GIZ	Finalise the revised regulation on Independent Electricity Distribution Networks.	early 2016
KEDCO	KEDCO management to decide role in relation to off-grid electrification – include in tariff submission to NERC in 2017.	early 2017

ES7 Grid Rollout Implementation (2018–2023) – Two Scenarios

In light of the Readiness assessment findings and recommendations above, two scenarios Fare identified following completion of Phase I – laying the essential groundwork. They differ in the trajectory of the year-to-year implementation of the physical program on-grid; the number of connections implemented each year and speed and acceleration. They also differ in the underlying expectations on improvements in key constraining/inhibiting factors, especially: bulk power supply adequacy and variability; quality of enabling policy framework announced, and its provisions and mechanisms for public funding to bridge the capex financing gap; and a conducive and supportive regulatory framework for retails tariffs consistent with the universal access policy. Table 5 shows the annual implementation profile.

- ***conservative scenario*** – reflects a cautious trajectory due to the degree of progress in the sector environment, with slow enactment of key enabling actions and/or processes and funding mechanisms; power supply adequacy picture takes more time as well as KEDCO's commitment and readiness to engage.
- ***best-practice scenario*** – reflects best practice experience in ramping up the physical rollout of implementation on a programmatic basis; that all key actors commit with top priority to putting their best efforts towards making best practice achievable in Nigeria; especially FGN (policy), NERC (tariff framework) and KEDCO (similar to their counterparts institutions in e.g. Indonesia, Kenya, Tunisia, Laos and Rwanda, where access was increased by a factor of five times in under three years).

Conservative scenario – in the first two phases of the programme for KEDCO, up to 2023, an investment financing requirement of US$ 362 million would be required for grid electrification. The on-grid electrification would begin cautiously with 30,000 new connections in 2018 rising to nearly 200,000 connections in 2023 and cumulatively over this period a total of nearly 550,000 new connections would have been made. The electrification rate would still be a relatively modest 37% at the end of 2023 (62% for institutions), compared with 33% today,[11] but this would be the foundation for of a much more rapid electrification rate over the subsequent years with an annual electrification rate of up to 500,000 per year and ultimately bringing the electrification rate to 83% by 2030 (94% for social and administrative institutions).

Table 5 Electricity access rollout programme (2018–2030)[a]

Access Rollout 2018–2030								
2015 (baseline):	**Conservative scenario**				**Best-practice scenario**			
	Grid connections: 1.24 mn.	**Grid access rate: 33%**	**Institutions connected: 3,350**	**Institutions access rate: 21%**	**Grid connections: 1.24 mn.**	**Grid access rate: 33%**	**Institutions connected: 3,350**	**Institutions access rate: 21%**
	New connections ('000)	**Progressive access rate (%)**	**New Institutions connected: ('000)**	**Progressive access rate (%)**	**New connections ('000)**	**Progressive access rate (%)**	**New Institutions connected: ('000)**	**Progressive access rate (%)**
2018	30.0	31%	600	25%	50.0	31%	600	25%
2019	40.0	31%	800	29%	75.0	32%	800	29%
2020	50.0	31%	1,100	36%	125.0	34%	1,100	36%
2021	93.0	32%	1,300	44%	200.0	37%	1,300	44%
2022	137.0	34%	1,400	53%	275.0	42%	2,050	57%
2023	198.0	37%	1,417	62%	375.0	48%	2,878	75%
Total additions 2018–2023	548.0		6,617		1,100.0		8,728	
Total connections by 2023	1788.0	37%	9,967	62%	2,340.0	48%	12,078	75%
Total connections added 2024–2030	3,200.0		5,153		3,360.0		3,032	
Total connections by 2030	4,988.0	83%	15,120	94%	5,700.0	95%	15,110	94%

[a] Note, the electrification rate declines between 2015 and 2018 because, despite some electrification in 2018, this has not kept pace with the growth in the number of households. The same is not true of social institutions where the total number of institutions is assumed to be fixed (instead the size of the schools and clinics grow as the population grows).

Best practice scenario – in the first two phases of the programme for KEDCO, up to 2023, an investment financing requirement of just over US$ 731 million would be required for grid electrification. The on-grid electrification would again begin relatively cautiously with 50,000 new connections in 2018 rising to 375,000 connections in 2023 and cumulatively over this period a total of nearly 1.1 million new connections would have been made. The electrification rate would still be nearly 50% at the end of 2023 (75% for the institutions). Over the subsequent years the annual electrification rate would increase up to 500,000 connections per year ultimately bringing the electrification rate to 95% by 2030 (94% for social and administrative institutions).

ES8 Investment Financing Prospectus – Grid Rollout (2018–2023)

Table 6 summarizes for the two scenarios the capital requirements of the physical programme. Cumulatively, the implementation of the conservative rollout is estimated to require US$ 2.5 billion by 2030, whereas US$ 3.2 billion are estimated for the best practice rollout. The year-to-year capital costs are also displayed, together with the investment need for the construction of LV and MV lines. As shown in the Table, the conservative scenario up to 2030 is relatively less focused on MV extension (US$ 680 million), and the investments are mostly directed to the construction of LV lines (US$ 1.7 billion). In

Table 6 Grid rollout capital investment cost (2018–2030)

		Conservative scenario 2018–2030							
		LV Intensification			LV Intensification			Total	
	Grid access rate	New grid connections ('000)"	$ per connection	Total cost ($ mn.)	New grid connections ('000)"	$ per connection	Total cost ($ mn.)	Average $/connection (LV+MV)	Total LV+MV/$ mn.
2018	31%	30	630	19	0	n/a	0	630	19
2019	31%	40	630	25	0	n/a	0	630	25
2020	31%	50	630	32	0	n/a	0	630	32
2021	32%	63	630	40	30	761	23	672	63
2022	34%	97	630	61	40	765	31	669	92
2023	37%	148	630	93	50	771	39	666	132
Total prospectus: 2018–2023		428	630	270	120	766	92	660	362
Total: 2024–2030		2,272	630	1,431	880	823	724	684	2,155
Total program life: 2018–2030		2,700	630	1,701	1,000	816	816	680	2,517
		Best-practice Scenario 2018–2030							
		LV Intensification			LV Intensification			Total	
	Grid access rate	New grid connections ('000)"	$ per connection	Total cost ($ mn.)	New grid connections ('000)"	$ per connection	Total cost ($ mn.)	Average $/connection (LV+MV)	Total LV+MV/$ mn.
2018	31%	50	630	32	0	0	0	630	32
2019	32%	75	630	47	0	0	0	630	47
2020	34%	100	630	63	25	765	19	657	82
2021	37%	150	630	95	50	771	39	665	133
2022	42%	200	630	126	75	780	59	671	185
2023	48%	275	630	173	100	792	79	673	252
Total prospectus: 2018–2023		850	630	536	250	782	195	664	731
Total: 2024–2030		1,850	630	1,166	1,550	848	1,314	729	2,480
Total program life: 2018–2030		2,700	630	1,702	1,800	839	1,509	714	3,211

Table 7 Impact on electricity demand

Year	Conservative		Best practice	
	Grid access rate	Demand impact (MW)	Grid access rate	Demand impact (MW)
2018	31%	7	31%	12
2019	31%	16	32%	29
2020	31%	28	34%	58
2021	32%	49	37%	104
2022	34%	81	42%	167
2023	37%	128	48%	257

the best-practice scenario, investments in LV lines are coupled with more investments in MV extension (US$ 1.5 billion), which are pursued more aggressively in time (starting in 2020 instead of 2021) and size (1,800 new connections versus 1,000 in the conservative scenario), and the main reason underpinning bigger achievements in access by 2030.

Table 7 presents the incremental impact on demand due to new connections by 2023, which is of 128MW in the conservative scenario and 257MW in the best-practice one. This should be manageable.

ES9 Investment Financing Gap (2018–2023)

The investment financing requirements are indicated in Table 8 below for the two electrification scenarios. This provisionally assumes an equity contribution by KEDCO's shareholders of 10% of the capital required.[12] This assumes that KEDCO's shareholders are comfortable that the regulatory framework going forward will reward them sufficiently for the risks entailed in such investments and that the market reforms continue to show results in terms of improved availability of electricity at the wholesale level.

The DISCOs were privatised at the end of 2013. The 2005 Electric Power Sector Reform Act prescribes the regulatory framework governing them, such that the companies should earn revenues that cover their costs and provide a reasonable market return on the capital invested. For the DISCOs, any investment they make in the expansion of electricity access would therefore need to be undertaken on a commercial basis.

The current owners of the DISCOs largely financed the acquisitions of the companies with loans securitised against the parent companies' assets, not

Table 8 Investment financing requirements for grid electrification ($ million)

	Conservative	Best practice
Capital investment requirement (2018–2023)		
2018	19	32
2019	25	47
2020	32	82
2021	63	133
2022	92	185
2023	132	252
Total capital investment	**362**	**731**
Minus: Assumed KEDCO equity (assumed 10%)	36	73
Connection charges	-	-
Plus technical assistance	11	16
Total financing gap	**336**	**674**

against the DISCOs' own profits. Nigerian commercial banks are currently unwilling to finance the DISCOs' investments or to finance revenue shortfalls when securitised against the DISCOs' revenues on terms that are consistent with the MYTO allowed revenue formula. Borrowing by the DISCOs on commercial terms to finance investments that are needed simply to create a stable platform to supply their existing customers is therefore problematic,[13] and major borrowing on commercial terms on any scale to expand the network is unlikely over the first phase of the electrification access programme. We tentatively assume for illustration purposes, that KEDCO shareholders may be willing to contribute 10% as an equity contribution (injections or retained profits).[14]

The resultant financing gap is assumed to be financed in some manner consistent with international best practices, highlighted above. Namely, the international experience with undertaking national electrification programmes has almost universally been largely financed through grants and concessionary loans[15] obtained by the Government from a variety of sources including Development Partners, Provincial Governments, Local Authorities, and on lent to the utility; on terms that ensure the commercial viability of the implementing agent, be it private or a public entity.

ES10 Financing Mechanisms and On-lending Terms for Public Funds Support

Based on international electrification rollout experiences[16] we suggest the establishment of an Electrification Fund that will be used to provide financial support to the private DISCOs when expanding access. The Fund will on-lend to DISCOs publicly raised funding on terms that are commercially viable, whether in the forms of grants or concessional loans, and will also keep DISCOs accountable for the financing received by monitoring and auditing their progress. As shown by international experience, it would be the Government responsibility to (i) secure the funding and (ii) ensure its availability before the electrification rollout takes off.

Various arrangements have been adopted worldwide for this kind of institution, but all of them responded to four main principles: transparency, accountability, independence and ex-ante funding of the programme. The Fund management will act as a trust fund payment agent and will be subject to specific rules and guidelines, with the supervision of NERC, governing cash-flow management and in particular how the financial resources are to be dispersed, monitored and, in the case of loans, returned. Finally, if the Fund is to be housed at an already existing agency (e.g. NERC), firewalls will have to be raised between the two entity to ensure the independence of both.

ES11 Technical Assistance

Technical assistance directed to key sector institution and agents is envisaged for the acquisition of the capacity required for the physical implementation of the access rollout and for the design and establishment of the enabling policy, legislations, and regulatory instruments that would set the stage for and ensure the successful execution of the electrification programme. Although some support should be directed toward the achievement of the key actions to be undertaken in the phase preliminary to the access rollout (described in Table 4), capacity strengthening will be needed on an ongoing basis during the implementation phase as the programme expands and accelerates.

A proposed technical assistance programme for capacity strengthening is described in Table 9. The programme is indicative, as the detailed scoping and its quantification will ultimately be defined by the more specific actions that KEDCO, the private sector and the FGN will decide to undertake to close the gaps and solve the ambiguities related to the policy and regulatory framework and to the role of public finance within the programme.

Two main areas of assistance are identified:

- ***Programme design:*** FGN to prepare and enact National Universal Access Policy coordinating grid and off-grid solutions comprehensive of targets and timetables and ensuring the commercial viability of the programme for the DISCOs together with affordability of electricity services for consumers. The policy will identify the key roles and responsibilities of sector stakeholders, fill the gaps for the establishment of an enabling legislative and regulatory environment, including mechanisms to monitor progress and a system of rewards and penalties of performance toward the achievement of the access targets;
- ***Physical implementation***: KEDCO to acquire the organizational capacities to implement the access scale up program (particularly in rela-

Table 9 Technical assistance (TA) programme (present–2023) – US$ million

Beneficiary	Measures	Conservative	Best practice
KEDCO	Planning (yearly program), tendering, management, supervision	2.5	3.0
	Strengthening of standard equipment specification, policies & procedures, procurement, mains records (location of plant)	0.5	0.5
	Customer Relationship Management	1.0	2.0
	Off-grid electrification assessment	0.5	0.5
	Sub-total	4.0	5.5
Ministry of Power	Planning, training for private contractors[a] other activities	5.3	8.0
Private manufacturers	Technical assistance to ensure manufacturing processes are up to standard	1.0	2.0
NERC[b]	To be determined		
REA[c]	To be determined		
Monitoring & evaluation		0.2	0.2
Ministry of Finance	To be determined		
Total		11.0	16.2

[a] This could be provided through NAPTIN, the electricity training institute based just outside of Kano.
[b] Nigerian Electricity Regulatory Commission (NERC).
[c] Rural Electrification Agency.

tions to planning, design, procurement, construction management, contracting, materials management, quality and standards) and supervise private sector contractors. The rollout will require large scale training of contractors to expand the work force and to bring private manufacturing up to standard, to be achieved for instance through the capacity expansion of the National Power Training Institute of Nigeria (NAPTIN).[17]

ES12 Off-grid Programme

Although connection to the grid is the least-cost solution in the long-run for most of the population, to ensure shared well-being and prosperity across the country, off-grid solutions should also be employed in coordination (in space and time) with and to complement grid developments.

More specifically, on the basis of the geospatial analysis, three categories of beneficiaries and uses of off-grid solutions can be identified:

- ***Long-term off grid*** – small communities or households residing in remote and isolated[18] areas where the grid is not recommended as the least-cost option by 2030. This is a small percentage of the total population (about 3% or 164,000 households by 2030) and of schools and clinics (about 6%).
- ***Pre-electrification*** – households residing in areas targeted for grid electrification in the latter part of the electrification programme which will thus be required to wait for several years (5 to 10, if not longer) for electricity access. This is potentially the largest component of the off-grid programme and, depending on the electricity access services provided, it could be characterized by two subcomponents:
  i. ***Tier 1&2 access delivery*** – The *economic* potential of this off-grid sub-programme refers to the ~3.3 million households that are not expected to receive access to the grid during the first 5 years of the electrification programme (up to 2023) regardless of the conservative or best-practice trajectory implemented (see Table 5)[19].
  ii. ***Tier 3+ access delivery*** – the *technical* potential for isolated mini- and micro-grids is identified in the latter segment of grid

development (in space and time), requiring the extension of MV lines and affecting ~1.8 million households (see also Table 5)[20].

These communities and households could be provided with sufficient power for essential electricity services such as household lighting, charging of mobile phones and other batteries and devices, and basic connectivity for schools and clinics to power computers, vaccine cold chain, and other services. Given the country's richness in solar resources, the technologies identified to provide off-grid services are pico-solar, solar home systems or diesel or hybrid mini-grids, although a throughout geospatial resource mapping of the country, completing the exercise started by GIZ, could reveal more renewable energy opportunities. For the Kano service zone, the costs associated to these technologies are in the range of US$50–100 for pico-solar, US$425 on average for solar home systems, and between US$500 to US$1,200 for mini-grids [21].

The costs associated to an off-grid programme will eventually depend on its size (that is, on the number of beneficiaries, their needs, and the technologies deployed) and are potentially substantial. For instance, given per-household SHS costs, the needs of the long-term off-grid beneficiaries could be met for around US$70 million. As regards pre-electrification purposes, the full rollout of the Tier 1 & 2 programme could require around US$ 450 million alone (with an average combination of pico-solar and SHS solutions).

Not strictly belonging to the off-grid access programme, but a potentially important segment of the off-grid market is constituted by the use of off-grid solutions for power back-up purposes. This market refers to households already provided with electricity access in 2015, or to be connected during the rollout plan, that could choose to rely on off-grid technologies for power back-up as long as the power supply provided by the grid is not reliable (high fluctuation of voltage, blackouts and load shedding). This could also constitute a significant component of the off-grid developments, as Nigeria is the second market for self-generators, far more expensive than efficient off-grid solutions would be.

Several factors constrain the growth of the solar market in Nigeria, particularly lack of access to finance for importers, distributors and consumers.[22] Hence, a financing plan—tailored to the current market structure—should be developed to support off-grid developments. The plan could envisage a combination of private sector and public sector-led endeavours:

- **Private sector-led off-grid –** the establishment of a credit line for off-grid electrification has proven to be very successful in countries such as Ethiopia and Bangladesh.[23] The financing mechanism can be designed to create a market-driven, private sector-led approach addressing some of the main issues preventing the off-grid market from taking off such as: access to finance at relatively lower cost of capital, improvements to the general lending environment, and identification of commercially viable delivery models. A line of credit could be opened to support DISCOs or small and medium sized private sector enterprises, and it could either become integral part of the Electrification Fund suggested for the on-grid rollout or established separately.
- **Public sector-led off-grid –** building on the National Renewable Energy and Energy Efficiency Policy adopted in 2015, stating that solar PV and SHSs will be used to power low to medium power applications such as communication stations, water pumping and refrigerator in public facilities in remote areas, the FGN could provide electricity access to all public institutions across the country.

The successful implementation of a large scale plan would also require tackling the other major obstacles to off-grid electrification. In particular, roles and responsibilities of sector institutions (e.g. Rural Electrification Agency) and stakeholders should be identified in the new market structure, leading to the establishment of an enabling policy and regulatory framework. This would include designing and enforcing quality standards and possible subsidy frameworks. The establishment of technical standards for off-grid technologies will also be key to protect protect investors' businesses after the arrival of the grid, after which off-grid solutions can become power supply back-ups and/or feed into the grid network. Finally, off-grid electrification will have to be undertaken in coordination with the actual spatial grid rollout of KEDCO in the next five to seven years.

Endnotes

1. The Prospectus' findings and recommendations are specific to the operating situation of KEDCO

DISCO and in light of the broader sector-wide framework and operating environment context of Nigeria today. At the same time, the analysis and recommendations of the Prospectus are informed by the rich lessons and experiences of relevant best practices from national electrification programs from numerous countries world-wide, that have successfully navigated their respective electrification programmes to universal or well advanced access (Morocco, Indonesia, Vietnam, Thailand, Tunisia, Kenya, among others). While in each instance the specific design features were home grown and tailored to their institutional environment and political economy, they all exhibit adherence to a set of core organizing principles and policy drivers that were necessary to enable their remarkable achievements.

2. As per discussions with the utility, we understand that connections targets for access scale up (to the estimated 69 percent without access today) may be revisited as DISCOs requested a review and update of the Performance Agreement parameters originally entered into with BPE.
3. All costs throughout the text and tables of this document are in constant 2015 US dollars, unless otherwise noted.
4. KEDCO estimates 1.5 km as the radius within which customers can be connected without additional MV line.
5. Ensuring adequate electricity supply to all customers served by KEDCO is an urgent. As of 2015, peak supply to KEDCO was typically around 250 MW with occasional higher peaks. This is well below the 1 GW that KEDCO estimates to be its total current demand. The 1.1 GW demand forecast here would be a) only for residential needs, and b) in addition to any unmet current need.
6. The access targets stated in the original Performance Agreements entered into with FGN/BPE have been essentially treated to this day, by all parties, as "pro forma place holders", to be revisited and revised appropriately; once the DISCO managements assumed control and gained some operating experience and obtained hand first knowledge of the ground realities facing the company.
7. Furthermore, this limited physical program is itself severely constrained on account of financing limitations as elaborated in following. KEDCO's accumulated deficit from privatization through 2015 is US$140 million. These figures are not debt per se; they represent the unpaid share of costs of bulk power purchases over this period, on account, NERC approved retails tariffs have not been set to allow for full recovery of this cost of service. KEDCO like all other DISCOs face this systemic under-recovery for their respective bulk power purchase costs. Regardless of the circumstances—that sooner or later, FGN together with NERC would need to satisfactorily and speedily resolve and redress this distortionary situation. Carrying such amounts of "accounts payables" on the balance sheets does not bode well for any DISCO to raise even short terms working capital from financial markets.
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9. As per NERC 2012 Regulation DISCOs are currently not allowed to impose connection charges, but the policy could be apt for revision at some stage of the access rollout.
10. For example: connection charges, utility equity, bill surcharge on non-poor customers within KEDCO.
11. This differs slightly from the figure in the least-cost geospatial analysis (31% access) as the Investment Prospectus was drafted on the basis of earlier results of the geospatial report.
12. At the time of drafting this Report, the shareholders, IFIs and development partners were not in a position to comment on their likely willingness to provide equity, debt or grants. The mix of financing provided here are therefore placeholder values.
13. World Bank estimates, February 2016.
14. The 10% equity contribution is consistent with international experience from countries such as Brazil, though it may be optimistic for Nigeria.
15. Examples described in the Report include Brazil where 90% of capital expenditures were financed from grants and concessionary loans and India where 100% is financed in this way.
16. Brazil, India and Chile, for instance.

17. NAPTIN was formerly part of the Power Holding Company of Nigeria (PHCN) but is currently owned by the Federal Government of Nigeria (FGN).
18. Defined by the geospatial report as distant more than ~100m from any neighbouring structure.
19. The successful experience of the WBG Lighting Africa and Lighting Global initiatives in Africa (see, for instance, the experiences of Kenya, Ethiopia and Tanzania) and Asia demonstrated that Tier 1 &2 products can be rapidly scaled-up, although not yet at the scale of ~3.3 million households (international experience suggest that ~30% of the size could be easily provided with access). World Bank Task Team Leaders estimates, 2016. For more information, visit: https://www.lightingafrica.org/.
20. No country has yet scaled-up an isolated mini- or micro-grid programme and the identification of viable business models is still a work in progress. However, international experience suggests that the market potential for this off-grid development is to date around 10% (i.e. 180,000 connections of the 1.8 million potential beneficiaries). World Bank Task Team Leaders estimates, 2016. The WBG Lighting Global started to operate in the Tier 3+ access delivery market.
21. The geospatial analysis identified the cost for a mini-grid with a service standard of 120 kWh/HH-year to be in the range of US$1,000-1,200 and for a 60 kWh/HH-year per customer service, between US$500 and US$700.
22. Other factors include: i) lack of an enabling policy and regulatory framework; (ii) lack of national quality standards for PV products and competition from low quality products; (iii) low levels of awareness of solar products, their advantages and ways to distinguish good quality products; and (iv) low availability of products due to lack of distribution networks in rural areas. Lighting Nigeria, 2015.
23. The Bangladesh SHSs program has been widely acknowledged as the most successful national off-grid electrification program in the world reaching 100,000 installations a month.

CHAPTER 1

Background to the Kano Service Zone and KEDCO

The Kano Electricity Distribution Company (KEDCO) is responsible for the distribution and supply of electricity to users in the three states of Kano, Katsina and Jigawa in the North West of Nigeria. This is referred to as the Kano service zone.

The states served by KEDCO are among the most populous in Nigeria with a combined population of 24 million or 4 million households. Kano is Nigeria's most populous of Nigeria's 36 states, while Katsina and Jigawa are 4th and 8th respectively.[1] All the three states have a relatively high population density. Today, electricity services in the KEDCO service zone are available to approximately 31% of the population. By 2030 the population of the three states is expected to reach 34 million, which will add a further two million households to the zone for a total of 6 million households. Under business-as-usual, the share of the population without access will grow, not diminish.

Although Kano is Nigeria's second largest city after Lagos, with a population of 3.6 million, it has only one quarter of the population of Lagos.[2] Katsina is the largest city in the state, but is relatively small with a population of less than 400,000. Dutse is the capital city of Jigawa.

North West Nigeria has a high concentration of poverty. The *Updated Poverty Map of Nigeria* prepared by Oxford University for the World Bank[3] indicates that Jigawa, Katsina and Kano are among the bottom ten states from Nigeria's 36 states in terms of poverty, with Jigawa, Katsina and Kano having 88%, 82% and 76% incidence of poverty respectively[4] compared with a national average of 53%. There is also a correlation between poverty and low electrification rates. Kano state alone has the highest number of households without electricity in the country (about 1.8 million).[5]

KEDCO was privatised, together with nine of Nigeria's other DISCOs at the end of 2013.[6] The Nigerian Electricity Supply Industry (NESI) had experienced years of under-investment and poor management in all parts of the electricity supply chain from fuel supply through to distribution and customer supply. This resulted in chronic power shortages across the whole country and privatisation was an attempt to remedy these problems. The new DISCOs management inherited a number of major issues including massive Aggregate Technical, Commercial and Collection (ATC&C) losses estimated after the completion of the privatization process at around 50%,[7] very poor customer record keeping and billing systems, poor network maintenance and overloading of lines and transformers, and very low levels of supply reliability. The problems are well documented.[8]

Although the 2010 Power Sector Reform Roadmap has achieved important goals, such as the completion of the privatization process for the generation and the distribution segments, the establishment of the Nigerian Electricity Regulatory Commission (NERC) and the Nigerian Bulk Electricity Trader (NBET), the speed of the ATC&C loss reduction programme that had been anticipated at the time of privatisation[9] has not been achieved and by the end of 2016 DISCOs will have accumulated almost US$3 billion[10] owed to the rest of the value chain.

KEDCO inherited ATC&C losses for about 49%, the majority of which are due to collection losses (37.4%).[11] The utility has now been in private ownership for nearly just over two years and management are attempting to come to grips with the problems of enumerating customers, collecting revenues and computerising basic accounting and management systems. The utility has accumulated deficits for US$140 million from 2013 until the end of 2015 and has received US$38 million from the FGN's Nigeria Electricity for Market Stabilization Fund (NEMSF) to pay upstream debtors at the beginning of 2015. However, in 2015 KEDCO was able to pay for 40% only of NBET invoices. Although the Performance Agreements came into effect in January 2015, cost-reflective tariffs were adopted but subsequently abandoned until February 2016, and the utility hasn't made any investments in improved efficiency beside the purchase of 64,000 meters at the beginning of 2016.[12]

With the implementation of the new MYTO 2015 in February 2016, tariffs were brought back to cost-reflective levels, however, to reduce the impact on end-consumers they were set at under-recovery for the first few years then allowing for over-recovery for the achievement of cost-recovery levels over a ten-year period. The size of under-recovery has been estimated at almost US$700 million for 2016 or 16% of expected total revenue for the whole sector. KEDCO is expected to achieve cost-recovery levels in 2018[13] and will hence keep accumulating deficits on account payables until then.

The regulatory framework for tariffs covering the next 5–10 years, does not make allowance for large scale electrification investment and this will need to be remedied before the electrification programme can be launched. Under MYTO 2015 tariff revenues are also in-sufficient (fixed charges were also removed)[14] to cover for 100% fall operating expenses. The capital expenditure allowance was also reduced by 20%[15] although DISCOs need to undertake priority interventions for loss reduction, network rehabilitation and meter installation to enhance revenue collection from existing consumers and help improve their financial position.

Wholesale generation and transmission is also inadequate to supply electricity to meet the demand implied by a rapid roll-out of electrification. The company is currently allocated with 8% of total of total generation capacity, but in 2015 received only 5% due to transmission constraints[16] and at the beginning of 2016 power supply was further decreased because of pipeline militant attacks. Power supply is therefore characterized by inadequacy and unpredictability, adding further pressure on KEDCO's planning capacity and financial conditions (tariffs are currently adjusted to changes in the baseline with a 6 months' time lag).

It emerges that the utility, together with all the other DISCOs, is still attempting to correct years of under-investment and poor management of the industry by focusing on stabilising its business and generating cash flow for the establishment of a solid financial and electrical foundation for moving forward. It is therefore not immediately in a position, financially or managerially, to prioritise a major electrification programme. Even if the Business Plan submitted at privatization (and entered into force in January 2015), listed as part of KEDCO's Minimum Performance Targets the connection of 350,000 customers in a five-year period, the target involved mostly meter deployment to existing consumers more than access provision.[17]

KEDCO has also limited experience of extending electricity grids on any scale, and it has limited human, materials and technical resources for undertaking a major electrification programme. However, these are not "systemic" challenges, and could quickly be addressable.

1.1 Geospatial Least-cost Plan for Universal Electrification

A geospatial analysis conducted by the Earth Institute under a separate contract with the World Bank disclosed that 1.24 million households in the three states are supplied from KEDCO's grid, representing an electrification rate of around 31%.[18] This is consistent with estimates of the current overall national grid electrification rate that is thought to be around 35%–40%.[19]

The geospatial analysis provided a detailed assessment of the optimal technologies to electrify the population of the Kano service zone and the investment cost to achieve 100% electrification by 2030. The plan identified the optimal electrification strategy for the year 2030 with the electrification of all households either through connection to the KEDCO grid or through off-grid solutions for remote population and isolated households or as interim solutions before grid arrival. The results of the geospatial analysis for the grid extension program, including highlights of the physical programme specific to each state belonging to the KEDCO service zone are summarized in Table 10 and Table 11 below.

The geospatial planning study found that:

- KEDCO has approximately 400,000 customers who are billed, of whom about 160,000 are currently metered (Component A: costumers).
- Another 840,000 households are supplied with electricity but are not metered and not registered as customers of KEDCO (Component B: consumers).
- Combining the customers with the consumers, 1.24 million households are currently supplied

Table 10 Electricity access in 2015 and grid extension programme for the KEDCO service area, 2015–2030

Electricity access status (2015)			Grid extension program (2015–2030)*				
Type of access	Population[a]		Components of grid program (Type of grid access planned)	Population[a,b]		Total CAPEX	CAPEX per HH
	(Households)	Percent		(Households)	Percent	(M USD)	(USD)
Grid access	7,430,000	31%	**A) Customers:** KEDCO has ~400K customers (2015); 63% need meters ($160/HH)	2,400,000 (400,000)	7%	$40	$160
	(1,240,000)		**B) Consumers:** ~840K HHs (2015 est.) consume power but do not pay KEDCO; all need meters & improved connections (~$180 per HH)	5,030,000 (840,000)	15%	$150	$180
No grid access	16,480,000	69%	**C) LV intensification:** By 2030, ~2.7 M HHs near the grid will need LV line, meter, connection (~$630 per HH)	15,680,000 (2,670,000)	47%	$1,670	$625
	(2,750,000)		**D) MV grid extension:** By 2030 ~1.8 M more distant HHs (>1.5 km from transformer) will need MV and LV line, connection, meter (~$840 per HH)	10,560,000 (1,760,000)	31%	$1,470	$835
Total	**23,910,000** **(3,990,000)**	**100%**	**Total**	**33,670,000** **(5,670,000)**	**100%**	**$3,330**	**$590**[c]

Source: Earth Institute, 2015.

[a] Based on census data, rural households have 6.1 persons on average vs. 5.8 for urban households. For simple computations and where the ratio of urban and rural households is unknown, 6 persons per household are assumed.

[b] It is assumed that population growth from 2015–2030 among those who currently have grid access (components A and B) will lead to net formation of new households that will need new connections requiring LV intensification (component C), MV grid extension (component D).

[c] Average household costs are calculated by summing all CAPEX costs across all program components and dividing by the total number of households served.

*Least-cost grid coverage is 97 percent.

Table 11 Technical summary for the LV intensification and MV extension components of the universal access programme for the KEDCO service area, 2015–2030

	Number household grid connections proposed		Grid length proposed (km)				New generation needed (MW) for residential connections	
			MV grid extension			LV intensification	MV grid extension	LV intensification
State	MV grid extension	LV intensification	MV	LV	MV/HH (avg, m)	LV		
Jigawa	510,000	482,400	6,600	15,200	12.9	13,200	120	120
Kano	640,000	1,523,200	5,600	18,700	8.7	34,800	170	400
Katsina	610,000	664,400	7,000	18,200	11.4	17,000	150	160
Sub-total	**1,760,000**	**2,670,000**	**19,200**	**52,100**	**10.8**	**65,000**	**440**	**680**
Total	**4,430,000**		**136,300**				**1,120**	

Source: Earth Institute, 2015.

from KEDCO's grid, whether paying for electricity or not (representing an electrification rate of around 31%).

- Between now and 2030 some 2.7 million households that lie within 1.5 km of the existing grid could be connected without extending the MV network. These would represent 45% of households in 2030. At an estimated cost of US$630 per connection, the total cost of this investment would be US$2.7 billion, or 90% of the overall cost of the electrification programme. The majority of this intensification will target Kano state, the most urbanized state within the KEDCO service area.
- Another 1.8 million households, or 30% of all households in 2030, could be connected economically by extending the MV network at an average cost of US$840 per connection inclusive of MV and LV costs. The total cost of this investment would be US$1.5 billion. This part of the electrification programme has been further subdivided by the Earth Institute into five phases, with increasing distance and cost. About 70% of the MV extension is targeted for Katsina and Jigawa, and the estimated MV line needed per household is higher in these two states (11–13 m) than in Kano (8–9 m).
- For approximately 3% of households in the KEDCO zone off-grid solutions would be the least-cost option by 2030, together with households and communities which are targeted for grid connection in the latter part (beyond the medium-term) of the MV grid extension plan for which transitional arrangements should be developed.
- The access rollout will add 5–5.5 million new residential customers with an incremental demand of about 1.1 GW, nearly 700 MW of which is attributable to intensification, while the other ~450 MW would result from MV grid expansion. It is assumed that each new KEDCO residential customer will add, on average, around 250–300 W of peak demand to the system (the weighted average is ~260 W).

The geospatial planning study conducted by the Earth Institute showed that there is a binary ***economic*** choice of electrification technology in the KEDCO service zone. This choice is between grid electrification on the one hand and distributed (mini-grid an off-grid) solar on the other. Because the majority of households lie within a short distance of the grid, for the majority of households (around 97%) the optimum electrification strategy *by 2030* was found to be connection to the main grid. The geospatial analysis also found that intensification of LV lines is the biggest component (over 115,000 of the 136,000 km of new grid lines) of the electrification plan, with the potential of providing access to almost 70% of the population by 2030 (including those already connected) for the KEDCO service area. This is illustrated in Figure 1.

The geospatial analysis indicates that only about 20% of public institutions (such as schools and clinics) are currently connected, although 80% of the most important ones, such as hospitals, already have grid connections to the existing network. The least-cost plan also indicates that by the end of the grid-electrification programme, about 94%[20] of the existing institutions will be connected. Two thirds of the institutions could be reached via LV intensification only, whereas the rest would require MV extension.

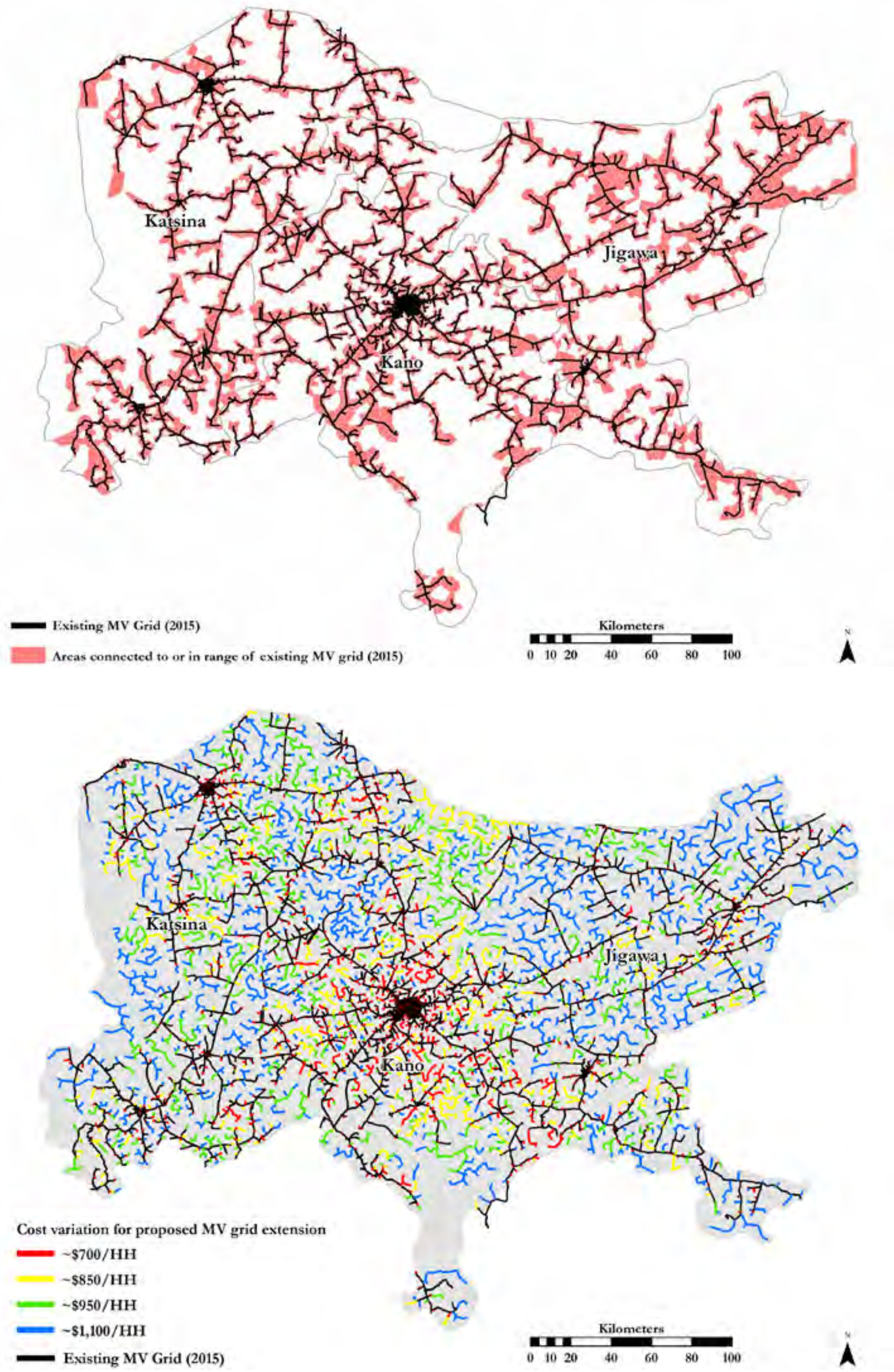
Although connection to the grid is the least-cost solution in the long-run for most of the population, for those communities that are geographically remote and/or scattered clusters, off-grid solutions (mini-grids, SHS and small-scale solar lighting/charging products) are the most cost-efficient. The geospatial analysis revealed that about 3% of the projected 2030 population will be best suited for off-grid solutions together with about 6% of the existing schools and clinic, as shown by Figure 2 (bottom).

The largest component of the off-grid electrification program potentially consists of households and communities[21] which are targeted for grid connections in the latter part (beyond the medium-term) of the 15-year MV grid extension plan and thus will be required to wait potentially for several years (5–10, if not longer) for electricity access. This could be a large group of beneficiaries, although, the size, target areas, cost and timing of a pre-electrification program will eventually also depend upon the actual implementation and sequencing of the rollout plan. The electrification possibilities for such pre-electrification areas are described in Annex 4.3.

Grid-coordinated pre-electrification plans will have to be developed as transitional measures since the grid is still the least-cost solution in the long-run, while at the same time designed to protect investors' businesses after the arrival of the grid. These pre-electrification transitional off-grid solutions could then become power supply back-ups and/or feed into the grid network.

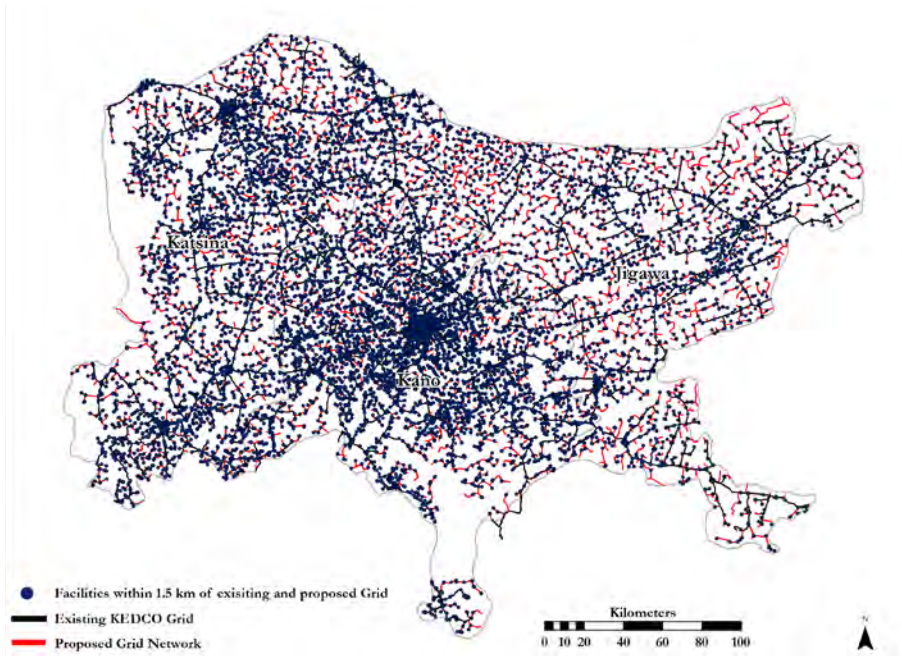
A plan for off grid will have to be separately developed and will have to identify the role of sector

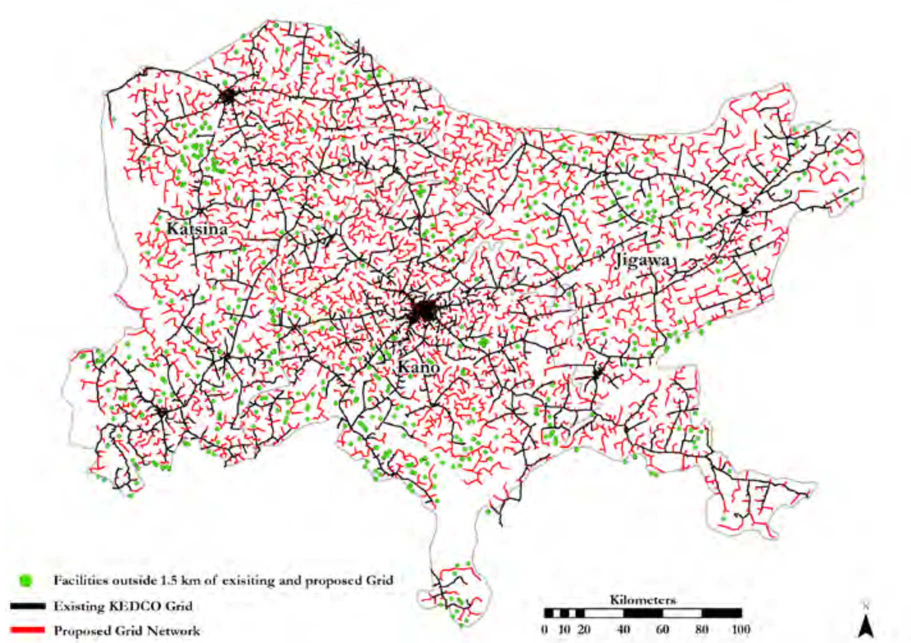
Figure 1 **Map showing existing grid lines and LV intensification connecting 69% of the projected population (top) and the prioritized grid expansion plan based on average cost per household (bottom), 2015–2030**



Source: Earth Institute, 2015.
Note: Nigeria Electricity Access Program (NEAP) Final Report, Geospatial Least-Cost Implementation Plan for Grid and Off-Grid Rollout (2015–2030), October 2015.

Figure 2 **Map showing social infrastructure (schools and clinics) planned for grid connection (2015–2030) (top) and beyond reach of existing and projected grid (2030) (bottom)**





Source: Earth Institute, 2015.
Note: Nigeria Electricity Access Program (NEAP) Final Report, Geospatial Least-Cost Implementation Plan for Grid and Off-Grid Rollout (2015-2030), October 2015.

institutions, enabling policies and regulations, solar market developments and service delivery ability and modalities of interested and qualified providers. The off-grid plan will also identify Tier 1 and 2 electricity needs (see Annex 4.2), costs, commercially viable investment opportunities, and financing prospectuses to attract and syndicate funding from the private sector, donors, and government institutions (see also Chapter 6).

Endnotes

1. 2006 Census, population.gov.ng.
2. CIA World Factbook, 2015. Lagos has a population of 13.1 million.
3. World Bank, *Updated Poverty Map of Nigeria*, Gething and Molini, June 2015.
4. This is a multidimensional definition of poverty adopted by the University. A person is identified as multidimensionally poor if they are deprived in at least one third of the weighted indicators including child mortality, education, access to infrastructure services, house size and assets.
5. 2006 Census, population.gov.ng.
6. The 11th DISCO was privatised but subsequently the private owner withdrew and it was taken back into government ownership.
7. The estimate of AT&C losses provided to bidders at the time of privatisation was much lower (around 28%) than the estimates revealed to the companies when they took over and gained full access to the DISCOs' records (around 50%).
8. See, for example: www.nigeriaelectricityprivatisation.com.
9. During the privatization process, bids were won on the basis of the ATC&C loss reduction targets.
10. World Bank estimates, May 2016.
11. The baseline of losses integrated into the new MYTO 2015 (implemented by NERC in February 2016) reports 37.4% of collection losses, 6.8% of commercial and 13.5 of technical losses. Note that the aggregate ATC&C losses of 48.7% is not additive but it is defined by a formula.
12. This purchase was made with the proceeds of the NEMFS. The loans received by the Fund are expected to be invested in metering and other key capital expenditures after paying upstream debts.
13. World Bank estimates based on the MYTO model, March 2016.
14. Arrears from the public administration, accounting for about 3% of total collection losses, were also removed. As per NERC 2012 Regulation DISCO are not allowed to impose connection charges.
15. For KEDCO capex fell from US$23.5 million to US$19 million. The capex allowance was reduced as DISCOs hadn't made use of it (in the absence of cost-reflective tariffs). See Also Annex 1.
16. The utility receives power from the Southern regions of the country, where power is produced.
17. As per discussions with the utility.
18. This report was drafted on the basis of the first findings of the geospatial analysis, indicating an electrification rate of 33%, which was subsequently slightly changed the 31% in the final version of the report. There were no major changes in the findings and in the year-to-year implementation.
19. The figures of 35-40% for grid electrification is taken from a draft Nigerian Electrification Action Plan prepared by the World Bank (September 2015). The overall electrification rate, including own-generation, was thought to be around 48% in 2011. The latter figure of 48% is from World Bank Energy Data Table indicators 2012 report. The figure of 35-40% was derived from figures prepared by NERC and the Bureau of Public Enterprise and extrapolated to 2015.
20. Among those that are not already connected to the KEDCO grid, 94% of all education facilities and all health facilities fall within 1.5 km of the MV grid lines proposed to meet residential needs.
21. The total number of households or communities targeted for pre-electrification will depend upon several factors that cannot be known at the time of this study, including the pace of grid expansion year-to-year, and the total funds available for these additional electricity systems.

CHAPTER 2

Indicative Electrification Programme

The geospatial plan concentrated on the optimal strategy for the year 2030 but in the sections below we show two scenarios—a **conservative** and **best practice** one—for the potential programme of connections over the period leading up to 2030. The conservative scenario assumes that greater time is need to allow improvements in the power market and the regulatory framework to take place, and that therefore it won't be possible to achieve universal electrification by 2030. The best-practice scenario is on the contrary consistent with the 2030 optimum identified in the geospatial plan and reflects worldwide best practice experience in ramping up the physical rollout with the quintuplication of access rates within three years and their tenfold increase within five years.[1]

Although expanded electrification is currently not KEDCO's priority, with the right regulatory, commercial and incentive framework, expanded electrification access should be an attractive option for the company to grow its business and expand its customer basis. For this reason, the electrification program is assumed to commence to start in 2018, allowing for a window to design the enabling policies and regulations for access rollout. The utility could use this time to concentrate on reducing losses and creating proper customer databases and billing systems and both the utility and the private sector could develop the capacity required by an electrification program.

Particularly key during the **preparatory time** up to 2018 will be the adoption of a National Universal Access Policy (see also Section 3.1). The strategic document will have to define the roles and responsibilities of sector institutions and include targets for annual connections coupled with monitoring instruments and funding mechanisms, including from public sources. In fact, no country has achieved universal electricity access without some form of public subsidy to finance the capital investment requirements (MV, LV and service connections), irrespective of whether the distribution sector was privatised or in public hands (see Chapter 4 for the financing of the capital costs of electrification programme).

The regulatory framework and tariff design will have to be tailored to the achievement of the goals set in the access policy. In particular, NERC will have to appropriately refine, expand and detail the MYTO framework in support of the access programme and update its oversight, review and verification processes and mechanisms. Furthermore, guidelines and regulations, including service standards, appropriate for the coordination of grid and off-grid efforts and for the development of an off-grid market, encompassing several service solutions (mini-grids, SHSs and pico-solar, but also interim and long-term solutions), will have to be designed.

The electrification targets for KEDCO and the DISCOs will have to be designed by the Federal Ministry of Power (FMP) in coordination with the Office of the Vice President through the Advisory Power Team—currently responsible for advancing the power sector reform—in coordination with NERC and the DISCOs, taking account of funding sources, grants available, and the impact on end-user tariffs. The targets will be firm for the initial periods, typically five-year periods to coincide with the multi-year tariff formulae, and indicative beyond that.

In addition, the preparatory phase should be used by KEDCO to strengthen its organizational and functional capacities to implement the access scale up program particularly in relations to planning, design, procurement, construction management, contracting, materials management, quality and standards. In parallel to the access rollout, KEDCO would also have to continue to further reduce technical and commercial losses and strengthen its financial stance.

The two scenarios presented differ in the trajectory of the year-to-year implementation of the physical on-grid programme in terms of number of connections implemented per year, speed and acceleration. They also differ in the underlying expectations on improvements in key constraining/inhibiting factors, in particular: bulk supply adequacy, quality of enabling policy framework, support from the regulatory framework for retail tariffs consistent with the universal access policy, and provisions and mechanisms for public funding to bridge the capital expenditure financing gap (discussed in Chapter 4). The best-practice scenario requires a significantly greater commitment from all parties to a programme of full electrification by the target date of 2030 and for these reasons would require more technical assistance to enable the programme to be accelerated (discussed in Section 2.3).

Table 12 below shows the year-to-year implementation profile and the corresponding access achieved by the two trajectories.

In the **conservative scenario** the on-grid electrification would begin cautiously with 30,000 new connections in 2018 rising to nearly 200,000 connections in 2023 and cumulatively over this period a total of nearly 550,000 new connections would have been made. The electrification rate would still be a relatively modest 37% at the end of 2023 (62% for institutions), compared with 31% today, but this would be the foundation for of a much more rapid electrification rate over the subsequent years with an annual electrification rate of up to 500,000

Table 12 Electricity access rollout programme (2018–2030)[a]

Access rollout 2018–2030								
2015 (baseline):	**Conservative scenario**				**Best-practice scenario**			
	Grid connections: 1.24 mn.	**Grid access rate: 33%**	**Institutions connected: 3,350**	**Institutions access rate: 21%**	**Grid connections: 1.24 mn.**	**Grid access rate: 33%**	**Institutions connected: 3,350**	**Institutions access rate: 21%**
	New connections ('000)	**Progressive access rate (%)**	**New Institutions connected: ('000)**	**Progressive access rate (%)**	**New connections ('000)**	**Progressive access rate (%)**	**New Institutions connected: ('000)**	**Progressive access rate (%)**
2018	30.0	31%	600	25%	50.0	31%	600	25%
2019	40.0	31%	800	29%	75.0	32%	800	29%
2020	50.0	31%	1,100	36%	125.0	34%	1,100	36%
2021	93.0	32%	1,300	44%	200.0	37%	1,300	44%
2022	137.0	34%	1,400	53%	275.0	42%	2,050	57%
2023	198.0	37%	1,417	62%	375.0	48%	2,878	75%
Total additions 2018–2023	548.0		6,617		1,100.0		8,728	
Total connections by 2023	1788.0	37%	9,967	62%	2,340.0	48%	12,078	75%
Total connections added 2024–2030	3,200.0		5,153		3,360.0		3,032	
Total connectionsv by 2030	4,988.0	83%	15,120	94%	5,700.0	95%	15,110	94%

[a] Note, the electrification rate declines between 2015 and 2018 because, despite some electrification in 2018, this has not kept pace with the growth in the number of households. The same is not true of social institutions where the total number of institutions is assumed to be fixed (instead the size of the schools and clinics grow as the population grows).

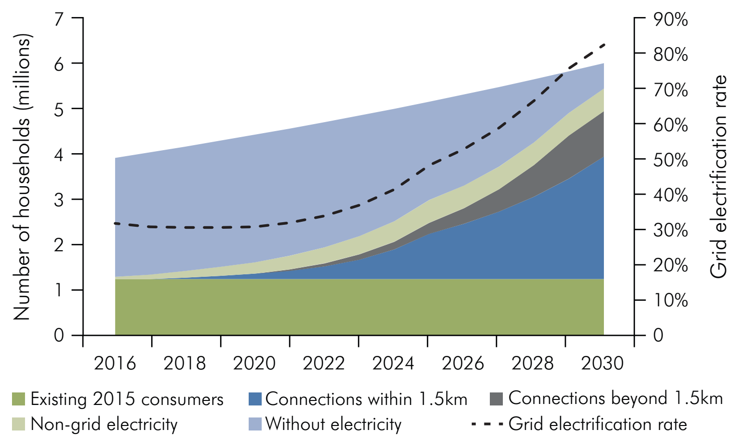
per year and ultimately bringing the electrification rate to 83% by 2030 (94% for social and administrative institutions). In the first two phases of the programme (up to 2023), an investment financing requirement of US$362 million would be necessary for grid electrification and the estimated increase in demand is of 128MW.

In the **best-practice scenario** the on-grid electrification would again begin relatively cautiously with 50,000 new connections in 2018 rising to 375,000 connections in 2023 and cumulatively over this period a total of nearly 1.1 million new connections would have been made. The electrification rate would still be nearly 50% at the end of 2023 (75% for the institutions). Over the subsequent years the annual electrification rate of up to 500,000 per year and ultimately bringing the electrification rate to 95% by 2030 (94% for social and administrative institutions). In the first two phases of the programme for KEDCO (again, up to 2023), an investment financing requirement of just over US$731million would be necessary for grid electrification and the estimated increase in demand is of 257MW.

From a physical implementation perspective, the two scenario differ as the conservative one is relatively less focused on MV extension (US$ 680 million) for the whole duration of the programme (up to 2030), and the investments are mostly directed to the construction of LV lines (US$ 1.7 billion). In the best-practice scenario, investments in LV lines are coupled with more investments in MV extension (US$ 1.5 billion), which are pursued more aggressively in time (starting in 2020 instead of 2021) and size (1,800 new connections versus 1,000 in the conservative scenario), and the main reason underpinning bigger achievements in access by 2030.

An **off-grid electrification** part of the programme would include pre-electrification communities that would otherwise wait several years for grid access. These areas are targeted for grid connections in the latter part (beyond the medium-term) of the 15-year MV grid extension plan and would otherwise be required to wait potentially for several years (5–10 years) for electricity access. Specific electrification technologies would be evaluated and selected—from options such as solar home systems and diesel or hybrid mini-grids—during a more detailed program design. A second group of off-grid electrification would provide non-grid solutions to areas where grid is not the recommended least-cost option within the period covered by the electrification programme. Finally, off-grid technologies could provide efficient

Figure 3 Conservative grid electrification programme for KEDCO



power back-up solutions. The off-grid programme is separately discussed in Chapter 6.

2.1 Conservative Grid Electrification Scenario

The conservative electrification trajectory for KEDCO is depicted in Figure 3 below, with the electrification rate starting at 33%[2] in 2015 and reaching 82% by 2030.

Specifically, there are an estimated 1.24 million households in the KEDCO service zone with an electricity connection (though not all are registered and billed). At the early stages of the electrification program, the grid electrification rate dips somewhat (from 33% to 31%) reflecting KEDCO 's focus on building its business (from customer enumeration and service to system automation) and the number of connections fails to keep pace with population growth.

The access scale-up program in the KEDCO service zone is assumed to begin in 2018 with some relatively small-scale intensification programme (within 1.5 km of the existing grid) that begins to build KEDCO's capacity and that of the private supply chains and contractors to undertake electrification. As also shown by Table 13, this lasts for a period of three years by which time an additional 120,000 new intensification connections are assumed to have been added by the end of 2020. The programme then begins to move into a more serious gear, with a target of one million intensification connections by 2025 and 2.7 million by 2030.

Table 13 Conservative grid electrification programme

	HH units	2015	2018	2023	2030
Existing 2015 KEDCO consumers	mn.	1.24	1.24	1.24	1.24
New intensification connections[a]	mn.	0.00	0.03	0.43	2.70
New connections w/MV extensions[b]	mn.	0.00	0.00	0.12	1.00
Total KEDCO grid connections	mn.	1.24	1.27	1.79	4.94
Grid electrification rate (HHs)		33%	31%	37%	83%
Total households in the KEDCO zone	mn.	3.80	4.16	4.85	6.00

[a] Defined as less than 1.5 km or less away from the existing grid.
[b] Greater than 1.5 km away from the existing grid. As the MV grid extends outwards, households will be closer to the grid but they are still included in the 'MV extension' category.

The MV grid extension programme begins in 2021 in this programme with the same broad approach of building capacity over the first three years and then ramping up the rate of electrification to reach one million connections by 2030. Contrary to what envisaged in the geospatial plan, in the conservative scenario KEDCO will not connect all 1.8 million potential connections involving MV extensions by 2030, but the electrification rate reaches only 82% by 2030, with the remaining section of the population for which grid connection is the least-cost solution to be electrified after 2030.

2.1.1 Capital costs – grid electrification conservative scenario

The capital cost associated with the KEDCO grid electrification programme is estimated at US$2.5 billion. As indicated in Table 14 below, the electrification program starts with an investment cost for the first five years (2018–2023) of US$362 million whereas the subsequent 7-year time slice shows a gradual ramping up of the program, with US$2.2 billion in the period 2024–2030.

Although the investment needs for the first five years of the electrification program are relatively modest, they have not been anticipated in KEDCO's tariff (MYTO) approved in February 2016 and they represent a substantial increase on the capital expenditure anticipated by NERC in its guidance to the DISCOs.[3] Some of this capital expenditure might be concessional financed, as discussed in Chapter 4, but there will be nevertheless a need for some capital expenditure to be financed by KEDCO and this implies the need for a revision to MYTO before the electrification program is launched in the KEDCO service zone.

The financing of the conservative electrification program and related financing gap are discussed in Chapter 4.

2.1.2 Increment of demand on the main grid from the conservative electrification program

Household electricity demand is calculated by the Earth Institute in the geospatial planning study at 200 Watts per household for poor households and 400 Watts for others.[4] The aggregate peak demand associated with the electrification programme described above is shown in Table 15 below and is calculated using these household demand parameters.[5]

2.2 Best-practice electrification programme

The best-practice electrification trajectory for KEDCO is depicted in Figure 4. The scenario also starts with an electrification rate of 33% in 2015, but as-

Table 14 Capital cost of the KEDCO grid electrification programme (conservative)

	Units	2018–23	2024–30	2018–2030
New intensification connections	US$ mn.	270	1,431	1,711
New connections with MV extension	US$ mn.	92	724	816
Total	US$ mn.	362	2,155	2,517

Table 15 Increased grid load associated with the conservative roll-out program

	Units	2018	2023	2030
Energy demand (sales) from new connections[a]	GWh	0	385	2,814
Maximum demand from new connections	MW	0	128	938

[a] Excluding technical losses. The energy needed from the wholesale market will be higher after taking account of network losses.

Table 16 Best-practice grid electrification programme

	HH units	2015	2018	2019	2020	2021	2022	2023	2030
Existing 2015 KEDCO consumers	mn.	1.24	1.24					1.24	1.24
New intensification connections	mn.	0.00	0.05					0.85	2.70
New connections w/MV extensions	mn.	0.00	0.00					0.25	1.80
Total KEDCO grid connections	mn.	1.24	1.29					2.34	5.74
Grid electrification rate (HHs)		33%	31%					48%	97%
Total households in the KEDCO zone	mn.	3.80	4.16					4.85	6.00

sumes that Nigeria achieves the full electrification plan laid out in the geospatial analysis with 97% electrification by 2030.

The best-practice scenario shown in Figure 4 also starts with an estimated 1.24 million households in the KEDCO service zone with an electricity connection (including unregistered and unbilled connections).

The electrification program in the KEDCO service zone is also assumed to begin in 2018 with an intensification programme (within 1.5 km of the existing grid) that begins to build KEDCO's capacity and that of the private supply chains and contractors to undertake electrification. As shown in Table 16, however, by 2023 it is assumed that KEDCO connects 1.1 million new households, both with intensification and grid extension, to its electricity grid bringing the grid electrification rate to 48% (compared with 37% in the conservative scenario). Thereafter, in the period 2024 to 2030, a further 3 million households would be connected through the program.

2.2.1 Capital costs – grid electrification best-practice scenario

The capital cost associated with the KEDCO best-practice electrification programme is estimated at US$3.2 billion. As shown in Table 17 below, similarly to the conservative scenario, the program estimates a relatively slow build-up of investment cost for the first period, with of US$ 731 million in 2018–2023.

The subsequent 7-year time slice shows a gradual ramping up of the programme, with US$ 2.5 billion in the period 2024–30.

Since the cost of an electrification program has not been anticipated in MYTO, the implementation of the best-practice scenario would also require a reexamination by NERC of the tariffs to finance capital expenditure, even in the event of available grants and concessionary financing.

The financing of the best-practice electrification program and related financing gap are discussed in Chapter 4.

Figure 4 Best-practice grid electrification programme for KEDCO

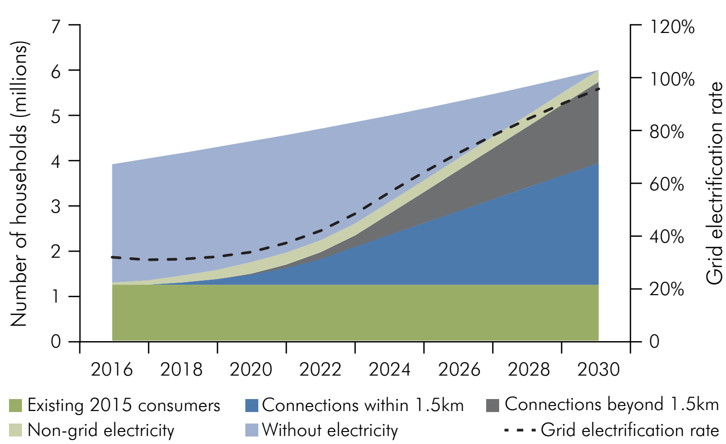


Table 17 Capital cost of the KEDCO grid electrification programme

	Units	2018–23	2024–30	2018–2030
New intensification connections	US$ mn.	536	1,166	1,702
New connections with MV extension	US$ mn.	195	1,314	1,509
Total	US$ mn.	731	2,480	3,211

2.2.2 Increment of demand on the main grid from the best-practice electrification program

Electricity demand in this scenario is calculated in the same way as the conservative scenario, as described above. The demand is summarised below.

2.3 Capacity Strengthening

Technical assistance directed to key sector institution and agents is envisaged for the acquisition of the capacity required for the physical implementation of the access rollout and for the design and establishment of the enabling policy, legislations, and regulatory instruments that would set the stage for and ensure the successful execution of the electrification programme. Although some support should be directed toward the achievement of the key actions to be undertaken in the phase preliminary to the access rollout (described in Table 4), capacity strengthening will be needed on an ongoing basis during the implementation phase as the programme expands and accelerates.

A proposed technical assistance programme for capacity strengthening is described in Table 18 below. The programme is indicative, as the detailed scoping and its quantification will ultimately be defined by the more specific actions that KEDCO, the private sector and the FGN will decide to undertake to close the gaps and solve the ambiguities related to the policy and regulatory framework and to the role of public finance within the programme.

The utility has currently limited experience in extending electricity grids on any scale, and it has limited human, material and technical resources for undertaking a major programme of connecting customers through intensification or grid extension, whether implemented with a conservative or best-practice trajectory. In fact, KEDCO accepts that to a large extent the electrification work will need to be contracted out to the private sector (both grid and off-grid). The utility will therefore need capacity building to supervise and manage a major electrification programme. As shown in Table 19, most of the technical assistance proposed for KEDCO would be directed towards supporting the utility's planning capacity. Overall, the best-practice scenario will require more technical assistance (from US$4 million in the conservative scenario to US$5.5 million) to enable the access programme to be accelerated, with greater resources allocated to manage the programme and to improve more quickly KEDCO's in-house capacity to plan, operate and manage an expanded network.

The private sector in North West Nigeria is experienced in undertaking electrification works,[6] though not on the scale necessary to achieve the electrification roll-out required for KEDCO and the work force will need to be expanded. Training and capacity strengthening can readily address this limitation capacity to the physical programme rollout. The Industrial Training Fund is currently used for training engineers and technicians for more complex equipment and processes. In the electricity sector, a wide range of training and services are currently provided by the National Power Training Institute of Nigeria (NAPTIN)[7] under contract to the electricity companies and the Institute could be expanded to

Table 18 Increased grid load associated with the best-practice roll-out program

	Units	2018	2023	2030
Energy demand (sales) from new connections[a]	GWh	35	770	3,540
Maximum demand from new connections	MW	12	257	1,180

[a] Excluding technical losses. The energy needed from the wholesale market will be higher after taking account of network losses.

Table 19 Technical assistance (TA) programme (present–2023) – US$ million

Beneficiary	Measures	Conservative	Best-practice
KEDCO	Planning (yearly program), tendering, management, supervision	2.5	3.0
	Strengthening of standard equipment specification, policies & procedures, procurement, mains records (location of plant)	0.5	0.5
	Customer Relationship Management	1.0	2.0
	Off-grid electrification assessment	0.5	0.5
	Sub-total	4.0	5.5
Ministry of Power	Planning, training for private contractors[a] other activities	5.3	8.0
Private manufacturers	Technical assistance to ensure manufacturing processes are up to standard	1.0	2.0
NERC[b]	To be detailed		
REA[c]	To be detailed		
Monitoring & evaluation		0.2	0.2
Ministry of Finance	To be detailed		
Total		11.0	16.2

[a] This could be provided through NAPTIN, the electricity training institute based just outside of Kano.
[b] The Nigeria Electricity Regulatory Commission is the regulator.
[c] Rural Electrification Agency.

provide the training necessary to enable the rollout of the electrification programme (linesmen, fitters, jointers, etc.).[8] The facility might also provide training suited to the development of isolated grids and solar home systems. The best-practice scenario sees a 50% increase (from US$5 million in the conservative scenario to US$8 million) in the technical assistance needed to fast-track the training of linesmen, fitters and jointers through the Ministry of Power (NAPTIN) and the doubling of the technical assistance (from US$1 to US$2 million) needed to bring private manufacturing processes up to standard for a large-scale programme.

Finally, power sector institutions may also need some technical assistance for the development of nation-wide access policy, coordinating grid and off-grid solutions—with targets and timetables on par with international best practices and supported by a legislative and regulatory enabling environment ensuring the financial viability of the programme for the DISCOs and affordability of electricity services for consumers. Combined with training of private contractors, support to increase the planning capacity of the Ministry of Power is envisaged as the area mostly in need of capacity strengthening (with US$5 million in the conservative scenario and US$8 million in the best-practice one). Although the support for the monitoring and evaluation of the program is currently quite small (US$200,000), this would be one of the most expensive but key activities of the access programme, to be detailed hand in hand with the access policy.

On the off-grid side, capacity strengthening will be needed to develop the rules and regulations governing the off-grid market and to define roles of responsibilities of sector stakeholders, including private and public actors. Since the role of Rural Electrification Agency needs to be re-defined in the new sector structure, tailored technical assistance will have to be detailed accordingly. The distribution companies may also have an interest in participating in the off-grid rollout (see also Chapter 6).

Endnotes

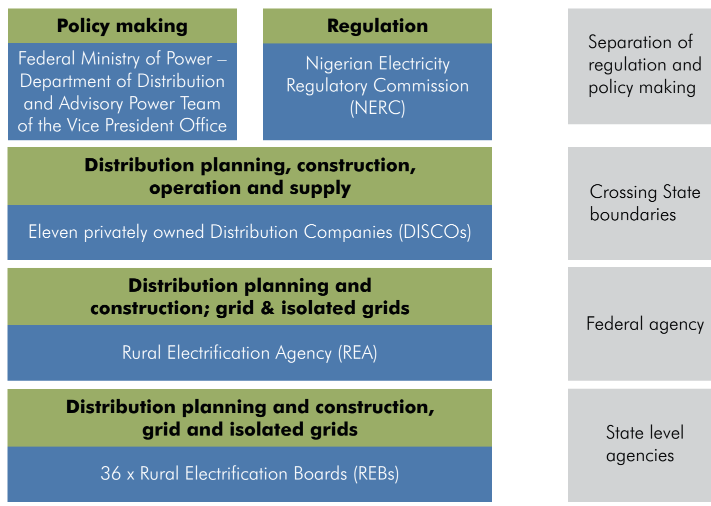
1. See, for instance, the successful experiences of Indonesia, Kenya, Tunisia, Morocco, Laos, Thailand, Vietnam and Rwanda.
2. This report was drafted on the basis of the first findings of the geospatial analysis, indicating an electrification rate of 33%, which was subsequently slightly changed the 31% in the final version of the report. There were no major changes in the findings and in the year-to-year implementation.

3. US$ 120 million over the five-year period, or US$24 million per year.
4. The classification of households was based on a geospatial poverty mapping study undertaken by Oxford University on behalf of the World Bank.
5. The household demand is understood to be the coincident, after-diversity maximum demand (i.e., the contribution to the aggregate peak demand of KEDCO). We assume this takes account of network losses (i.e., is measured at the bulk supply point entering the KEDCO grid). If the demand parameters are non-coincident or before diversity, the aggregate demand would be lower. The projection assumes that some households migrate to higher consumption bands after a time.
6. Private contractors typically provide in-house training for linesmen, fitters, jointers, etc.
7. NAPTIN was formerly part of the Power Holding Company of Nigeria (PHCN) but is currently owned by the Federal Government of Nigeria (FGN).
8. A facility already exists on the outskirts of Kano city and although equipped with modern equipment, it does not currently provide training in the skills needed for the expansion of the distribution network.

CHAPTER 3

The Role of the Policy Maker and Regulator

The current institutional framework for policy making, regulation, delivery and financing in the electricity distribution sector is depicted in the figure on the right.



The Federal Ministry of Power (FMP), in coordination with the Advisory Power Team of the Office of the Vice President (currently responsible for advancing the power sector reform), is the policy making arm of the Federal Government. NERC is the regulator and determines tariffs and allowed revenues for the DISCOs based on principles laid out in the primary law. NERC also ensures that Federal Government policy is appropriately implemented.

The Rural Electrification Agency (REA) and the Rural Electrification Boards (REBs) have, in the past, both had the primary function of supporting the former Federal-owned and vertically integrated electricity company[1] to develop electricity grids in rural areas and to then connect them to the national grid to be owned and operated by the electricity company.

When the electricity supply chain was Government-owned, the roles of REA and the REBs in helping develop distribution networks were clear but post-privatisation they need to be revised and properly designed and harmonized with the remit and mandate of DISCOs throughout their service areas.

The following Section 3.1 discusses the need for an access policy and electrification targets to be adopted by FMP, the role of NERC in allowing the recovery of costs in electrification incurred by the DISCOs, in incentivising the electrification programme, and in making provisions for cross-subsidisation.

3.1 A National Policy for Universal Access

The 2001 National Electric Power Policy (NEPP) is still the operational policy issued by the FGN. The policy explicitly specified a target for electrification to increase to 75% by 2020 towards the achievement of universal access by 2030.[2] However, these targets were established when the electricity sector was fully state-owned and before privatisation plans were introduced in 2005 with the Electric Power Sector Reform Act and were not actively pursued.

The NEPP electrification targets were designed to help prioritise actions by the Federal and State Governments, donors, REA and REBs and to help identify funding needs, but they were not actively pursued. They are not firm targets with financial penalties or rewards for the DISCOs nor a monitoring and oversight system was ever set in place.

In 2010, the Federal Government of Nigeria initiated a bold power sector reform program encompassing the entire value chain with the launching of the Power Sector Reform Roadmap. The Roadmap operationalized the 2001 National Electric Power Policy and the 2005 Electric Power Sector Reform (EPSR)

Act. The Road Map, subtitled "A Customer Driven Sector-Wide Plan to Achieve Stable Power Supply", stemmed from the acknowledgment of consumers' frustration for unreliable and/or absence of electricity services. While achieving many of the goals set in the Roadmap, including the completion of the privatization process,[3] the reform didn't detail targets and timetables for electricity access enhancement, nor the role of the FGN in a mostly privatized setting.

A necessary pre-requisite for any meaningful and sustainable start of an electrification programme, is for FGN to adopt a National Universal Access Policy, encompassing much more than a statement of vision. The revision of the 2001 NEPP should be tailored to the sector structure presently in place and include specific access targets accompanied by enabling policies. As demonstrated by international best practice experiences, no country has achieved universal access without a strong government commitment, vision and policy, whether in a privatized power sector setting or in a state-owned one.[4]

The National Universal Access Policy should address clearly the full range of enabling policy measures and drivers necessary to facilitate the DISCOs in scaling up electricity access in a systematic and comprehensive manner for provision of adequate, affordable and reliable access to all residents. The Policy should also define the roles, mandates and accountabilities of sector institutions (including at the local levels) and stakeholders, and include targets for grid annual connections and off-grid developments coupled with monitoring instruments and funding mechanisms, including from public sources. The regulatory framework and tariff design will have to be tailored to the achievement of the goals set in the access policy; and guidelines and regulations, including service standards, appropriate for the coordination of grid and off-grid efforts and for the development of an off-grid market, encompassing several service solutions (mini-grids, SHSs and pico-solar, and interim and long-term provisions), will have to be designed.

The Policy and the electrification targets for KEDCO and the other DISCOs will have to be determined by the Federal Ministry of Power (FMP) with the Office of the Vice President through the Advisory Power Team—currently responsible for advancing the power sector reform—in coordination with NERC and the DISCOs, taking account of funding sources, grants available, and the impact on end-user tariffs. The targets will be firm for the initial periods, typically five-year periods to coincide with the multi-year tariff formulae, and indicative beyond that.

Access targets will have to be designed and concretely pursued. The targets are necessary because there is currently no licence obligation to connect customers on demand and because, for affordability reasons, there is a need for cross subsidies between customer groups. Cross-subsidisation means that the DISCOs will be incentivised to maximise sales to the non-subsidised customers and to minimise the connection of subsidised customers.

The targets will have to have a concrete function in helping to identify investment expectations in the multi-year tariff orders (issued by NERC) and to provide incentives (penalties and rewards) for DISCOs for failing or succeeding in achieving the targets—again to be monitored and implemented by NERC.

The electrification investments and the targets will need to be established based on discussions between FMP, NERC and the DISCOs. The MYTO should be revised reflect the cost of investments in electrification and the DISCOs should be held to account in achieving the electrification targets implied by the investment programme. NERC should also appropriately update its oversight, review and verification processes and mechanisms to play its due role in support of the electrification programme.

To the extent that NERC regulated tariffs, combined with other revenue resources potentially available to the utilities (e.g. equity) do not allow for a complete recovery of the capital expenditure required by the access scale-up programme, the Policy would also need to identify the means and mechanisms for providing public funds to bridge the financing gap. In fact, no country has successfully achieved universal or well-advanced degree of electricity access without a strong financial commitment from the Government, even in a privatized setting (see also Chapter 4).

The discussion between FMP, NERC and the DISCO will then centre around the utilities' business plans, financial projections and financing needs (for investment in all aspects of their business—not only for electrification) and grants and concessionary funding available to the DISCOs and the implications, positive or negative, for end-user tariffs. More specifically, NERC will have to oversee the balance between DISCOs financial viability on the one hand, and of affordability on the other.

Endnotes

1. Until 2005 this was the Nigerian Electric Power Authority (NEPA) and between 2005 and 2013 it was the Power Holding Company of Nigeria (PHCN).
2. The 2006, Rural Electrification Strategy and Implementation Plan, developed by econ ONE for the Bureau of Public Enterprise mentions a policy of universal access to electricity by 2040. We have not obtained a copy of the original NEPP.
3. Under the reform program, PHCN was unbundled and privatized into eleven distribution and six generation companies (40 percent of shares are owned by the FGN), and the Gas Aggregator Company of Nigeria (GACN) and a bulk power trading company (Nigeria Bulk Electricity Trading Company, NBET) were established to facilitate private investments in power generation. A management contractor was brought in for the Transmission Company of Nigeria (TCN) and an independent regulator (Nigerian Electricity Regulatory Commission, NERC) was established. By early 2015, in accordance with the newly established market-based rules, the majority of the PHCN successor companies had signed power trading contracts with NBET and NERC had adopted and revised the 'Multi-Year Tariff Order' (MYTO) to cost-reflective levels.
4. Best practices include the ones of Vietnam, Thailand, Lao PDR, Kenya Rwanda, Tunisia and Morocco. For more information, see also Independent Evaluation Group (2015), "World Bank Group Support to Electricity Access, FY2000-2014. An Independent Evaluation", Washington D.C.

CHAPTER 4

Financing and Implementation of the Access Program

KEDCO was privatised at the end of 2013 and has been in operation for two full financial years—2014 and 2015. During the first of those two years, the company slowly began to piece together a set of financial statement but a set of audited accounts for 2014 and 2015 were not available at the time of this report.[1] After privatization, the DISCOs have no obligation to publish their financial statements, but the absence of accounts or financial data is itself an indication of poor financial health.

The most recent and available estimated of KEDCO's historical accounts, and projections of its future financial performance were submitted by the utility (on request of NERC) for the definition for MYTO 2015. Some of the highlights are provided in Table 20 below. The estimates incorporate the loss reduction targets that KEDCO committed to in the Performance Agreement and Business Plan submitted at the time of privatization,[2] which entered into force in January 2015 (one year after the completion of the privatization process) when cost-reflective tariffs where firs adopted (but abandoned in April 2015).[3]

The projections show improvements in KEDCO's future financial performance. The Table shows a rapid growth in electricity sold, in part because of a halving of technical and commercial losses from 18% in 2015 to 9% in 2021. However, the growth is primarily due to an expected increase in electricity available from the national grid and a resulting increase in electricity sales to customers with an underlying growth rate of 10% per annum. At the same time, the company is expected to reduce its collection losses from nearly 33% in 2015 to 6.3% by 2020. These improvements are designed to allow

Table 20 KEDCO's past and forecast financial position

	2014	2015	2016	2017	2018	2019	2020	2021
Electricity purchased wholesale (GWh)	3,142	2,414	3,091	4,132	5,213	6,110	6,644	7,374
Losses (technical and commercial – % of purchased)	18.1%	18.1%	17.5%	15.1%	12.1%	10.0%	9.1%	9.1%
Sales (GWh billed)	2,573	1,977	2,549	3,530	4,602	5,512	6,054	6,719
Growth in sales (%)	7%	–23%	29%	38%	30%	20%	10%	11%
Average tariff (NGN/ kWh)	31.70	45.04	36.27	30.24	27.65	25.80	25.09	25.18
Revenues (billed – NGN million)	81,567	89,058	92,472	106,753	127,272	142,197	151,911	169,144
Collection losses (%)	37.4%	32.8%	25.1%	17.4%	11.7%	8.2%	6.3%	6.3%
Revenues collected (NGN million)	51,094	59,872	69,289	88,207	112,347	130,491	142,344	158,492
Bulk electricity costs (NGN million)	39,058	38,765	54,028	71,582	94,399	110,936	121,241	135,986
Operating costs incl. depreciation (NGN million)	8,438	8,897	9,416	10,073	10,772	11,514	12,340	13,170
Earnings before interest and tax (EBIT) (NGN million)	3,598	12,211	5,846	6,552	7,176	8,040	8,762	9,336
Return on regulated asset base (RAB)	9.7%	24.4%	11.2%	11.8%	12.3%	13.1%	13.5%	13.7%
Allowed return on RAB	11.0%	11.0%	11.0%	11.0%	11.0%	11.0%	11.0%	11.0%

Source: KEDCO's submission to NERC for MYTO 2015 (December 2015).

the average tariffs to fall from NGN 36.3 (US$ 0.18 cents) per kWh in 2015 in 2015 by nearly one third to around NGN 25 (US$ 0.12 cents) in 2020.

However, the fulfilling of the financial projections is hindered some of the underpinnings of KEDCO 's Business Plan and by developments in the power sector after the completion of the privatization process, including recent power supply issues due to militant pipeline attacks.

In fact, the ATC&C loss reduction targets submitted at privatization (upon which bids were won and now integrated into MYTO 2015) and the corresponding investment needs (shown in Table 21 below) were designed to be consistent with the capital expenditure allowance contained in the MYTO model at the time of privatization, allowance that was decreased by 20% in MYTO 2015.[4] The decision was taken by NERC because DISCOs had made no use of the capital expenditure allowance they had. The only significant loss reduction capital expenditure made by KEDCO after privatization was the purchase of 64,000 meters at the beginning of 2016 with the proceeds of the Nigeria Electricity Market Stabilization Fund (NEMSF), entity established by the FGN to provide loans through the Central Bank of Nigeria (CBN) to finance the losses accumulated by the DISCOs after privatization. However, the absence of loss reduction investments by KEDCO and other DISCOs was also due to their inability to justify the borrowing needed to fund capital expenditure in the absence of cost-reflective tariffs.[5]

Although ATC&C losses were assessed and validated only after privatization,[6] and incorporated into the last round of MYTO revision, a throughout and bottom-up assessment of the utility's investment needs hasn't been conducted yet. For instance, as shown in Table 12 above, the Business Plan projected investments for US$13 million in metering, but the average price per meter modelled was of about US$27,[7] whereas current estimates are of US$160,[8] not lastly because the company decided to deploy smart meters only. Furthermore, the geospatial analysis disclosed that approximately 1.5 million households would need a meter, in order to achieve the target of 100% metering in five years as set in the Performance Agreement, a target 65% bigger in numbers of households than what detailed in the Business Plan (which targeted the deployment of 512,164 meters).[9]

Table 21 Summary of KEDCO's non-access investment requirements (US$ million)

Year	Metering	Loss reduction	Other	Total
2015	3.8	2.4	18.8	25.0
2016	4.7	1.0	15.7	21.5
2017	1.2	8.8	13.2	23.2
2018	1.5	13.5	14.1	29.1
2019	1.8	18.0	0.6	20.5
Total	13.1	43.8	62.4	119.3

Source: KEDCO Business Plan, 2012 (entered into force in January 2015).

The new MYTO 2015 also removed losses coming from MDAs non-payments from the ACT&C figures contained in the tariffs, which in the case of KEDCO accounts for about 3% of the overall losses.[10] Because of the delay in the adoption of cost-reflective tariffs (two years after completion of the privatization process) and the removal of FGN arrears from collection losses, the DISCOs are currently negotiating with BPE and NERC a re-sculpting of the over the next five years of the targets, which is further delaying their implementation.

Furthermore, the achievement of KEDCO's financial projections is hampered by the deficit that all DISCOs have been accumulating since privatization. In aggregate, DISCOs have only been able to pay for around 70% of the electricity purchased from NBET[11] and by the end of 2015 their accumulated arrears had amounted to nearly US$2 billion.[12]

Although figures on the deficit accumulated by KEDCO since privatization are not publicly available, KEDCO is estimated to have accumulated US$140 million since privatization.[13] The utility has been significantly underperforming with regards to it payments for energy received from generation companies and in 2015 was only able to pay 40% on average of NBET invoices (see also Annex 1). The company also received US$38 million in the first quarter of 2015 from the Nigeria Electricity Market Stabilization Fund (NEMSF)[14] as loans funded by the Central Bank of Nigeria (CBN) to pay upstream debtors.[15]

In addition, to manage the increase in tariffs for end consumers, the new MYTO 2015 implemented in February 2016 was designed to smooth the tariff path by allowing under-recovery of revenues initially and over-recover in later years over a ten-year period. For the whole sector, this is expected to lead to an increase in the DISCOs' collective deficit to nearly US$ 3 billion by the end of 2016,[16] corresponding to an under-recovery of 16% of expected total revenues. KEDCO is expected (by MYTO) to have fully cost-recovery tariffs (i.e. no under-recovery) by the beginning of 2018, when it is therefore also expected to stop accumulating deficits. Until then, KEDCO will not be able to recover its operating costs and will only be able to undertake minor capital expenditures.

The achievement of the targets set out in the Business Plan and reflected in MYTO 2015 would also be difficult as Nigerian commercial banks are currently unwilling to finance the DISCOs' investments or to finance revenue shortfalls when securitised against the DISCOs' revenues on terms that are consistent with the MYTO allowed revenue formula. Commercial banks are not familiar with the distribution segment of the power sector nor have yet developed long-term lending instruments necessary for infrastructure development. Borrowing by the DISCOs on commercial terms to finance investments that are needed to create a stable platform to supply their existing customers is currently already problematic.[17]

Finally, the projected 10% increase in sales will also be affected by power availability,[18] which is currently hampered by transmission constraints and more recently by a resurgence of militant attacks in the producing regions of Nigeria. The utility is currently allocated with 8% of total generation capacity, but in 2015 it only received 5% due to transmission constraints in the wheeling of power from the Southern regions of the country, where power is produced, to the Northern regions. Total available power supply has been 3500MW (KEDCO received 280MW) on average in 2015, and has decreased to an average of 3150MW in the first quarter of 2016 (252MW received by KEDCO) due to militant attacks.

The fall in bulk electricity supply over the past months due to gas supply problems and optimism in the power supply figures during the last major MYTO review should, in theory, in accordance with the MYTO tariff formula be corrected through an increase in allowed revenues. However, it is estimated that the tariff increase would be of 50% for the whole sector (including foreign exchange devaluation),[19] and would very unlikely be implemented without triggering further public opposition.

4.1 Capital Costs of the Electrification Programme (2018–2023)

The 2005 Electric Power Sector Reform Act prescribes the regulatory framework governing the DISCOs, such that the companies should earn revenues that cover their costs and provide a reasonable market return on capital invested. For the DISCOs, any investment they make in the expansion of electricity access would therefore need to be undertaken on a commercial basis.

The current owners of the DISCOs largely financed the acquisitions of the companies with loans securitised against the parent companies' assets, not against the DISCOs' own profits. As Nigerian commercial banks are currently unwilling to finance the DISCOs' investments or to finance revenue shortfalls when securitized against the DISCO's revenues on terms that are consistent with the MYTO allowed formula, any major borrowing on commercial terms on any scale to expand the network is unlikely over the first phase (2018–2023) of the electrification access programme. As noted, borrowing to finance investments that are needed to reduce losses and create a stable platform to supply their existing customers is already problematic.[20] Furthermore, given the scale of the of the required investment, it would be a challenge to secure substantial commercial funding for the initial six-year period to cover the capital costs between US$360 and US$730 million (shown in Table 22 below).

Under current regulations, DISCOs are not permitted to charge residential customers a connection fee, so that customer contributions will not, at least under the current framework, reduce the financing

Table 22 Capital investment requirements – Grid electrification (US$ mn.)

	Conservative	Best-practice
Capital investment requirement (2018–2023)		
2018	19	32
2019	25	47
2020	32	82
2021	63	133
2022	92	185
2023	132	252
Total capital investment	**362**	**731**
Minus: Assumed KEDCO equity (assumed 10%)	36	73
Connection charges	—	—
Total financing gap	**326**	**658**

necessary for the electrification programme. KEDCO's owners may themselves wish to finance some of the investment—the rate of return allowed in current NERC regulations does make such investment attractive in theory. However, given regulatory uncertainties over tariffs experienced over the past 12 months, the risks for equity investment is potentially high.

The investment requirements of the least-cost access scale-up programme are substantial. For the grid component, capital expenditures for about US$3.3 million are estimated over a 15-year period, with an annual average of US$220 million over the implementation period. For the time frame covered by this Prospectus (2018–2023), the on-grid financing needs for the two rollout scenarios are summarised in Table 13 below.

An overall capital cost for grid electrification of US$ 362 million will be required for the conservative scenario and just over US$ 730 million will be needed for the implementation of the best-practice scenario. The financing gap for 2018–2023 is projected to be of US$326 for the conservative scenario and of US$658 for the best-practice one.

Relevant experience from other nations that have successfully navigated a universal access rollout unambiguously indicates that no country has achieved universal access without significant and sustained levels of public funding to finance a substantial portion of the capital investment requirements (capex), irrespective of whether the distribution sector was privatised or state-owned. This applies in particular to the early stages of access rollout implementation when revenues from other sources are inadequate to finance LV and MV lines and service connections. Combined with the adoption of a National policy for Universal Access with targets and timetables, Governments' financial commitment constitutes a key driver of performance for the success of a large scale electrification programme.[21]

For instance, in Brazil the state and regional governments provided 85% of the investment costs through grants and concessionary loans while the private owners contributed 15%. In India, the electrification programme was 100% government funded with 90% provided by central government and 10% by the state governments. In Chile, the electrification programmes were awarded on the basis of the provider offering the lowest subsidy requirement. Successful programs, that have either achieved universal access or are well advanced in their rollout, were also undertaken in Morocco, Tunisia, Kenya, Rwanda, Vietnam, Thailand and Indonesia, amongst others.

The financing gap shown in Table 13 provisionally adopts an equity contribution by KEDCO's shareholders of 10% of the capital required.[22] This assumes that KEDCO's shareholders are comfortable that the regulatory framework going forward will reward them sufficiently for the risks entailed in such investments and that the market reforms continue to show results in terms of improved availability of electricity at the wholesale level. This equity may come from retained profits or from external calls on cash from the shareholders—essentially it is the same source. Investment in distribution is normally regarded internationally as a low risk business but the returns on investments in distribution in Nigeria are currently uncertain and for this reason we have suggested only a 10% equity contribution.

For the reasons described above commercial borrowing is not anticipated. To the extent that NERC regulated tariffs—guided by FGN policy on access—combined with other revenue sources potentially available to a utility (e.g. equity, connection charges, bill surcharge on non-poor customers) do not allow recovery of 100 per cent of the capital expenditures (capex) of the access scale program, public funds will be needed to bridge the shortfall (i.e. the investment financing gap associated with the access rollout implementation each year). Therefore, the resultant financing gap for both scenarios (US$326 for the conservative scenario and of US$658 for the best-practice one—or 90% of the investment requirements) is assumed to be financed by the FGN, consistently with international best practices, through grants and concessionary loans. The FGN could obtain the financing from a variety of sources including Development Partners, Provincial Governments, Local Authorities and will on-lend to the utility on terms that ensure its commercial viability.

Although the mix of financing provided here are placeholder values we note that the equity share assumed (10%) is broadly consistent with the share adopted for example in Brazil's electrification scheme, though higher than in India (see Annex 6). The equity and loan contribution would have to be discussed with KEDCO management and owners and other potential financing institutions. The split among financing sources (equity, grants, concessionary loans) will be determined at syndication.

Based on international electrification rollout experiences[23] (described in Annex 6), we suggest we suggest the establishment of an **Electrification Fund,** similar to that adopted in Brazil, that will be used to provide financial support to the private DISCOs when expanding access. The Fund will on-lend to DISCOs publicly raised funding on terms that are commercially viable to the DISCOs, whether in the forms of grants or concessional loans, and will also keep DISCOs accountable for the financing received by monitoring and auditing their progress. Grant funding will make it easier for the electrification targets to be accepted by all parties and co-funding of investments through donor grants and concessionary loans will also help lower the actual or perceived risks for KEDCO's owners. As shown by international experience, it would be FGN's responsibility to (i) secure the funding and (ii) ensure its availability before the electrification rollout takes off.

Various arrangements have been adopted worldwide for this kind of institution, but all of them responded to four main principles: transparency, accountability, independence and ex-ante funding of the programme. The Fund management will act as a trust fund payment agent and will be subject to specific rules and reporting requirements, with the supervision of NERC, governing cash-flow management and in particular how the financial resources are to be dispersed, monitored and, in the case of loans, returned. Finally, if the Fund is to be housed at an already existing agency (e.g. NERC), firewalls will have to be raised between the two entity to ensure the independence of both.

For the KEDCO investment programme, loans will be made to KEDCO. These loans may be provided by the proposed Fund, together with grants. If concessionary loans are provided this may not, under the current regulatory framework, benefit end-users because the rate of return allowed by NERC is independent of the actual cost of borrowing (this should be remedied by changing the regulatory formula so that the benefit of concessionary debt is passed on to end users). Grants will be made to KEDCO (through FGN or from FGN) but grant-funded assets should not be included in KEDCO's net asset base and the company should not be allowed to recover these costs from customers through a return on net fixed assets and depreciation charges. Ultimately, KEDCO's customers will repay the equity and loan components of the KEDCO investment programme through tariff revenue designed to cover operating costs including depreciation and a return on net fixed assets.

4.2 Investment Needs in Generation and Transmission

The analysis reveals that the electrification programme will lead to an increase in electricity demand of between 130 MW and 260 MW by 2023 (and around 1,000 MW by 2030)—this is just for KEDCO (if the programme is rolled out to other DISCOs, a similar increase in demand would be expected for the other ten DISCOs). Generation capacity is a pooled resource and this demand will be supplied from the TCN grid and allocated to KEDCO and other DISCOs. KEDCO's current allocation is 8% but this could potentially be negotiated upwards if it's demand increases faster than other DISCOs and sufficient capacity is available. KEDCO's demand resulting from new connections will be in addition to the anticipated underlying increase in electricity demand which is expected by NERC to grow at 10% per annum, with generation rising to over 14,300 MW by 2028[24] from NERC's assumption of approximately 4,120 MW available in 2015.[25]

Generation has been privatised and the current framework envisages that new generation capacity will be developed by the private sector and sold to the bulk trader (NBET). Some significant new power plants are currently under development with state funding through the NIPP (see also Annex 1). The first private sector power plant reached financial closure in December 2015 (Azura-Edo, part of a 2,000MW IPP)[26] and the framework for attracting private investment in power generation therefore exists (specifically, the wholesale tariffs available for generators are attractive), guarantees are available, and a number of conditional licenses have been issued by NERC. Partial risk guarantees are being provided by the World Bank and AfDB. The World Bank has provided or is providing loans to support the upgrade of hydropower projects.[27] Relatively small-scale but grid connected renewable generation is being developed in Nigeria—these projects are being provided with grant support from the German government/EU/GIZ and the Clean Technology Fund (under World Bank management). JICA is also providing grants for a grid connected solar power plant.

It must be assumed that in time there will be adequate generation capacity to satisfy the growing demand. There will be substantial investment financing needs of the private sector for generation to satisfy the growth in demand. This is not covered by this Investment Financing Prospectus. We note that a generation masterplan study is underway, financed by JICA.[28]

Transmission remains state-owned (Transmission Company of Nigeria – TCN) and substantial investment will also be required both to satisfy the underlying demand growth and to meet the demand to be generated by an electrification programme. The transmission system to the KEDCO franchise area has a transfer capability constrained to less than 250 MW. The maximum demand that has actually been supplied was 286 MW. Because of the transmission constraint, KEDCO is not able to take its full 8% allocation of generation from the wholesale market. In 2015, KEDCO was able to take about 5% if its allocation.

The unreliable pipeline infrastructure is currently leaving as much as 1,500 MW of installed power generation capacity stranded[29] in the sector and the management contractor has identified several areas of critical investment that are needed for the transmission system (estimated at about US$8 billion) to achieve a wheeling capacity of at least 20,000 MW by the year 2020. Some of the financing for TCN is provided from the World Bank, AfDB,[30] AFD[31] and JICA.[32] We also note that a transmission planning study has been contracted by TCN with World Bank funding. Again, the investments required for transmission network expansion, reinforcement and rehabilitation are not covered by this Investment Financing Prospectus.

Endnotes

1. Verbal communication with KEDCO.
2. For all DISCOs, bids were won on the basis of the loss reduction targets to be implemented over a five-year plan.
3. The delay in the enforcing of the Performance Agreements signed at privatization was due to absence of cost-reflective tariffs, which were introduced for the first time in January 2015 but then abandoned in March 2015 after political backlash triggered by the tariff increase.
4. In the case of KEDC the capital expenditure allowance decreased from US$23.5 million to US$19 million per year (NGN 4.7 billion to NGN 3.8 billion).
5. After the adoption of cost-reflective tariffs in January 2015, which determined the activation of the privatization Performance Agreements, tariffs were reverted back to their previous levels in March 2015 because of political backlash.
6. Although privatization bids were won on the basis of targets for loss reduction, at that time an accurate assessment of ATC&C losses was not available, and an agreement was reached between NERC and the DISCOs to assess and validate them for their incorporation in the following round of MYTO revision (adopted in January 2015). MYTO 2015, adopted in February 2016 is based on the same set of validated losses. For KEDCO, losses were established at almost 49% whereas in the Business Plan were estimated at 40%.
7. In 2015 terms, accounting for inflation for 2012–2015.
8. As reported by the geospatial analysis. More recent conversation with the utility indicate that the average price per meter could also be higher, around US$220.
9. KEDCO's Business Plan submitted at privatization. The target for meter deployment included the provision for new connections (this mostly referred to regularize existing consumers) but not for R1 new customers.
10. According to Energy Markets and Rates Consultants (EMRC), formerly Mercados EMI, a consultancy providing advisory services to Nigerian DISCOs.
11. Verbal communication with NBET.
12. World Bank estimates, February 2016.
13. World Bank estimates, March 2016.
14. The Nigeria Electricity Market Stabilization Fund covers the losses accumulated from privatization until the end of 2015. To cover for the 2016 arrears, the FGN was supposed to issue a bond, but at the time of writing it hadn't been issued yet.
15. Any surplus after paying the debt was expected to be invested in metering and other key capex.
16. World Bank estimates, February 2016.
17. World Bank analysis, February 2016.
18. The increase in sales is also due to the projected reduction in ATC&C, but primarily due to increase in electricity availability in the national grid, as noted at the beginning of the Section.
19. World Bank estimates, March 2016.
20. World Bank analysis, February 2016.
21. For an overview of the key drivers of performance and successful experiences world-wide see also IEG (2015), "World Bank Support for Electricity Access FY2000–2014", Washington D.C.
22. At the time of drafting this Report, the shareholders, IFIs and development partners were not in a position to comment on their likely willingness to provide equity, debt or grants. The mix of financing provided here are therefore placeholder values.
23. Brazil, India and Chile, for instance.

24. The basis for NERC's forecast is unclear and, in particular, it is unclear how much is assumed to relate to increased electrification and how much to increased supply to existing customers and consumers. Strictly speaking, the NERC forecast is a supply forecast rather than a demand forecast.
25. This differs slightly from the figure provided by NBET for 2015 of 4,500 MW of available generation capacity.
26. The facility is expected to produce 450 MW in the first phase, and then increase production up to 2,000 MW. The commissioning was supported by guarantees from the World Bank Group and construction started in January 2016. For more information, visit: www.azurawa.com.
27. Approximately US$100 million for rehabilitation of power plants, focusing particularly on water resource management. Some.is funded from the Carbon Fund.
28. Japanese International Cooperation Agency.
29. Also due to lack of policy and regulatory reform in the gas sector, together with outdated commercial frameworks and price ceilings.
30. US$ 150 million soft loan for budget support to the Ministry of Power that is being used for transmission investment.
31. US$ 170 million loan.
32. US$ 200 million loan.

CHAPTER 5

Current Tariff Regime and the Electrification Program

The latest electricity tariffs were approved in February 2016 through version 2015 of MYTO. These removed the fixed charge from tariffs and substantially raised the kWh charges for all DISCOs including KEDCO.

A key policy aspect of the current tariff design is maintains a 'lifeline' tariff, classified under the label 'R1' and has been fixed at NGN 4/kWh (US$0.02/kWh) for many years without a fixed monthly charge. In MYTO 2015, the R1 tariff has been fixed again at this same level until 2024. The R1 tariff of NGN 4/kWh compares with KEDCO's MYTO 2015 tariff for the standard non-lifeline residential customer (R2A) which is nearly five times greater.[1]

The R1 tariff is available to customers who are assessed to have a monthly consumption of less than 50 kWh per month. However, this is not an increasing block tariff and customers paying the R1 tariff may consume in excess of 50 kWh per month. A regulation issued by NERC allows the DISCOs to convert R1 customers to R2 if their consumption exceeds 50 kWh per month for three months in succession. Immediately after privatisation, KEDCO's R1 customers were using nearly 100 kWh per month on average in December 2013[2] but this had since fallen to around 50 kWh by the start of 2015 as customers were re-allocated to the R2 category. The R2 category currently represents the largest group by customer numbers and kWh sales as shown in Table 24 below.

Cost reflective residential tariff designs would normally mean that residential customers pay ***more*** than commercial and industrial customers per kWh. The R2 tariff already incorporates some element of cross-subsidy from non-residential customers to R2 customers and the R1 customers are very heavily subsidised from non-residential consumers.

Table 23 KEDCO selected tariffs (February 2016 after tariff revision)

Tariff category	Feb. 2016 tariff (NGN/kWh)
R1: residential <=50 kWh/month, single phase	4.0
R2A: residential >50 kWh/month, single phase	20.3
C2: commercial LV maximum demand[13]	36.3
D2: industrial LV maximum demand[14]	37.3
D3: industrial HV maximum demand[15]	37.3

Source: NERC website.

Table 24 KEDCO customer numbers and kWh consumption (May 2015)

Tariff category	Customer numbers	MWh sales (% of total)
R1: residential lifeline	48,141	4%
R2: residential >50 kWh/month	250,471	48%
C2: LV commercial LV	630	6%
D2: industrial LV	138	11%
D3: industrial HV	31	17%
Other	12,572	15%
Total	311,983	100% (60,942)

Source: Extracted from KEDCO billing data.

The regulatory framework determining electricity revenues and tariffs is set out in the 2005 Electric Power Sector Reform Act and the tariff regulations have been developed by NERC using a building-blocks model to establish the allowed revenues and tariffs on a multi-year basis. Allowed revenues for the DISCOs are calculated on the basis of operating costs including depreciation on fixed assets plus rate of return on net fixed assets plus pass-through of elements such as the bulk purchase tariff and the fees for TCN, NBET and NERC. At the start of the control period, the tariffs are fixed for its whole duration (with periodic adjustments for the non-controllable components) and the DISCOs are expected to manage their costs efficiently. If they can make above average profits by being cost-efficient, they are allowed to keep the profits and the shareholders receive good dividends but if DISCOs are inefficient, they make low profits and the shareholders receive no or low dividends.

There is currently no allowance for an electrification programme in the multi-year tariff calculations approved by NERC and the tariffs hence do not allow the DISCOs to recover large scale electrification costs. Combined with the absence of an electrification allowance, the DISCOs have no incentive to embark in a large scale effort as there are no targets set in place, nor mechanism for rewards and penalties, and the "sculpting" of the tariffs (with MYTO 2015) is not even allowing for cost recovery. The companies are currently focused on facing the inefficiencies inherited from years of under investments in the sector and on stabilizing their business and generating cash flow.

However, if the capex programme requirements of the access roll-out are reflected in the allowed revenue calculations used to design the MYTO tariffs, and if the tariffs are affordable (to be examined by NERC), then customer revenues would be sufficient to allow the DISCOs to make a respectable return on their investment and to service their debts. Looking forward, with the right regulatory, commercial and incentive framework, expanded electrification access should be an attractive option for the companies to grow their business and expand their customer base. According to NERC, the inclusion of electrification financing into the tariff could also be approved during a minor tariff review (conducted every six months), provided that the DISCOs submit their plans and a proof of some degree of implementation.[3]

5.1 Equity Concerns and Strategic Rollout of the Electrification Programme

Ensuring the affordability of electricity services will be key for the success of the electrification programme and for the equitable development of the country. The design and implementation of the enabling policy and regulatory framework for the access programme will therefore have to go hand in hand with ensuring affordability and shared prosperity.

The analysis of the available datasets on income, expenditure and geographic distribution of poverty (described in detail in Annex 2) indicates that the R2[4] tariff is only affordable by around half of the population and that there is a huge step change in in affordability between the very cheap R1 lifeline tariff (NGN 4/kWh with no fixed monthly charge or US$0.02/kWh) and the conventional R2 tariff (above NGN 18.75/kWh in 2020). The R1 is affordable to 85% of the population, but the bottom 15% of households would not be able to afford it. Finally, the top 30% of households would, however, be able to afford the to-end industrial tariffs of around NGN 34/kWh (US$0.17/kWh).

Large sections of new costumers of the electrification programme would therefore belong to the R1 tariff category, which would not be attractive for a profit-maximizing company. In fact, we assume that the regulation adopted by NERC in 2012 requiring DISCOs to not impose connection charges would be maintained during the first phase of implementation of the rollout plan (2018–2023), although it could be apt for revision at a later stage. Since the maximum tariff that could be earned from lifeline customers is NGN 4/kWh and the cost of supply is over NGN 20/kWh, the utility would sell every unity of electricity sold at a loss and would rather connect profit-making customers, leaving large sections of the population—and the ones most in need—without electricity provision.

However, this is a common issue of any large scale electrification program. Experiences worldwide show that new connections should be strategically approached with the combination of low-income customers with profit-making ones. Hence, KEDCO, as well as the other distribution companies, could combine R1 lifeline connections with commercial and industrial ones. This tactic would prove to be particularly successful during the first stages of the rollout as there is a large base households and businesses to connect. Over time, economic growth will increase energy consumption and the base from which to collect the cross-subsidy narrowing the financial gap to be recovered when connecting new customers. The utility should therefore evaluate these strategic options when designing its access roll-out strategy.

The alternative would be an increase in the cross-subsidy, which we modelled for illustration purposes only, as it can and therefore should be avoided.

5.1.1 Potential cross-subsidy implications of the access rollout

In this sub-section we consider the potential consequences on revenue requirements and tariffs of connecting large numbers of R1 customers through the electrification program. The impact is illustrated using the conservative electrification scenario and the implementation of the realistic although more ambitious best-practice trajectory would have an even higher impact.

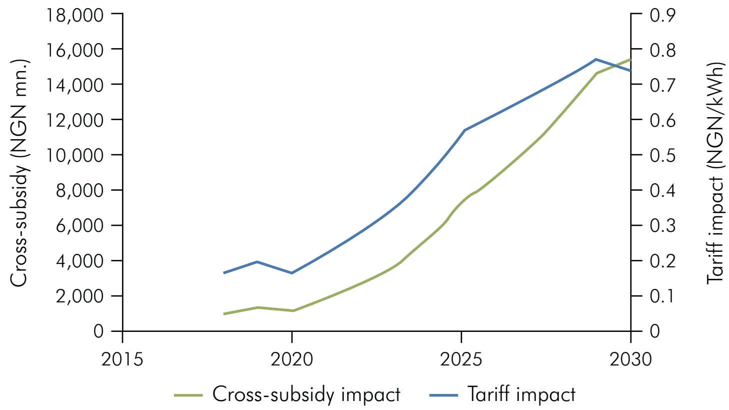
Although R2 customers currently constitute KEDCO's biggest category of sales, since large proportions of the population of North West Nigeria will not be able to afford the conventional residential R2 tariff[5] we assume that 70%[6] of the new households connected to an access roll-out plan will initially be connected as R1 customers and then migrate to the R2 tariff.

We model the conservative connection scenario to determine the total requirement for cross-subsidy to new R1 connections, with the following assumptions:

- KEDCO serves approximately 70,000 R1 customers at the present time
- 70% of the additional 3.7 million customers added through the conservative scenario by 2030 through intensification and grid extension will be connected as R1 customers
- These R1 customers will increase their consumption and become R2 customer after five years[7]
- The R1 tariff will remain at NGN 4/kWh
- KEDCO's cost to serve R1 customers is the same as the cost to supply the average R2 customer[8]
- The difference between KEDCO's R2 tariff and the R1 tariff is the required cross-subsidy.

Following these assumptions, we forecast that the value of cross-subsidies required will increase steadily, reaching **NGN 15 billion per year (US$ 77 million)** in 2030 (see Figure 5). This is a relatively large amount compared with KEDCO's annual revenues today (approximately US$100 million billed, but significantly less collected), but by 2030 this is predicted by NERC to represent a much smaller share of the total. While the cross-subsidy amount steadily increases in absolute terms, the number of non-R1 customers, and their consumption, also increases steadily, thereby increasing the base across which the cross-subsidy can be collected. We calculate that the incremental amount needed on top of the average cost-recovery tariff to meet the cross-subsidy will rise to **NGN 0.7/kWh** by 2030 (US$ 0.003/kWh) or around 4% of KEDCO's commercial tariffs. Initially, however, the increase would be more modest at around NGN 0.2/kWh in 2020.

Figure 5 Impact of cross-subsidy requirements on tariffs



The above assumes that the consumption of non R1 customers connected through the electrification program, and of those R1 connections moving to the R2 tariff category after five years, grows at 10% per year, allowing a large base of consumption from which to collect the cross-subsidy. If this grows instead at, for instance, 5% per year, the impact on tariffs will be greater.

The continuation of the current subsidy policy in tandem with the electrification program would not add substantially to the bills of non-residential consumers. However, the tariff increase of NGN 0.7/kWh by 2030 assumes an increase in consumption of current and future non R1 customers of 10%, which could eventually be lower. In addition, as shown by Figure 5, the tariff increase is relatively flat until 2020, but becomes steep in the following years up to 2030, and its impact would therefore be felt more by KEDCO customers. Finally, the tariff increase assumes that new R1 customers will progressively migrate to the R2 category after five years, which may or may not happen.

Endnotes

1. The multiple of six is slightly misleading as the high average R2 tariff is partly the result of load shedding resulting in low kWh supplied to R2 customers so that the costs are divided over a smaller denominator. If supply could be increased, the average R2 tariff should fall.
2. 96 kWh per month in December 2013 and increasing to 139 kWh per month in March 2014.
3. Based on discussion with the Regulator.
4. Here we use the 2020 tariff as the benchmark as this is when the electrification programme is likely to take off. The tariff then is expected to be NGN 18.75/kWh with no standing charge.
5. Though R2 is far from reflecting the costs of supplying residential customers, it is the closest approximation we have available.
6. This is an assumption. The income profile of customers over the period to 2030 is not known so the household expenditure data provides only partial guide to the proportion connecting as R1 customers.
7. This is an assumption. KEDCO has relatively few R1 customers compared with R2 and it is therefore likely that customers relatively quickly exceed 50 kWh per month.
8. This assumption is incorrect since the cost to supply new (mostly R1) customers will be greater than that to supply customers in more urban areas, but it is a first approximation.

CHAPTER 6

Off-grid Electrification

The geospatial analysis revealed that given the demographic settlement patterns and relevant technical, economic and financial parameters provided primarily by domestic sources (including KEDCO), connection to the grid is the least-cost solution in the long-run for most of the population. However, the analysis also allows to identify the potential and scope for an off-grid electrification programme, to be coordinated (in space and time) with and to complement grid developments. In particular, two categories of beneficiaries can be identified: long-term off-grid and pre-electrification. The use of off-grid solutions for power back-up is also discussed, although not strictly belonging to an off-grid access programme.

Long-term off-grid refers to small communities or households geolocated in remote, isolated (defined as distant more than ~100 m from any neighbouring structure[1]) or scattered areas where the grid is not recommended as the least-cost option by 2030. They constitute a small percentage of the population, about 3%, corresponding to about 126,000 households in 2015 and growing to 164,000 by 2030 and to 6% of current schools and clinics.

The largest component of the off-grid electrification program potentially consists of beneficiaries of **pre-electrification** solutions, that is, households and communities which are targeted for grid connections in the latter part (beyond the medium-term) of the 15-year MV grid extension plan and thus will be required to wait potentially for several years (5 to 10, if not longer) for electricity access. Depending on the electricity access services provided, pre-electrification beneficiaries could be characterized by two subcomponents:

i. **Tier 1&2 access delivery**[2] – The *economic* potential of this off-grid sub-programme refers to the ~3.3 million households that are not expected to receive access to the grid during the first 5 years of the electrification programme (up to 2023) identified by this Prospectus (illustrated in Table 3), regardless of the conservative or the best-practice trajectory implemented. The successful experience of the World Bank Group Lighting Africa and Lighting Global initiatives in Africa (see, for instance, the experiences of Kenya, Ethiopia and Tanzania) and Asia demonstrated that Tier 1&2 products can be rapidly scaled-up, although not yet at the scale of ~3.3 million households[3].
ii. **Tier 3+ access delivery** – the *technical* potential for isolated mini- and micro-grids is identified in the latter segment of grid development (in space and time), requiring the extension of MV lines and affecting ~1.8 million households (also illustrated in Table 3). Although no country has yet scaled-up a mini- or micro-grid programme, well designed pilot schemes (a pilot scheme has been recently launched by GIZ) can aide in the identification of viable business models to support the spreading of distributed generation[4].

To ensure shared well-being and shared prosperity across the country, these communities could be provided access with sufficient power for essential electricity services such as household lighting, charging of mobile phones and other batteries and devices, and basic connectivity for schools and clinics to power computers, vaccine cold chain, and other services. Grid-coordinated pre-electrification plans will have to be developed as transitional measures when the grid is still the least-cost solution in the long-run, while at the same time designed to protect investors' businesses after the arrival of the grid (i.e. ensuring technical compatibility between off-grid solutions and the distribution network). These pre-electrification transitional off-grid solutions could then become power supply back-ups and/or feed into the grid network. The electrification possibilities for such pre-electrification areas are described in Annex 4.3.

Not strictly belonging to the off-grid access programme, but a potentially important segment of the off-grid market is, in fact, constituted by the use of off-grid solutions for power back-up purposes. This market refers to households already provided with electricity access in 2015, or to be connected during the rollout plan, that could choose to rely on off-grid technologies for power back-up as long as the power supply provided by the grid is not reliable. Nigeria is affected by chronic high voltage fluctuations, blackouts and load shedding, making the country the second market for self-generators, far more expensive than efficient off-grid solutions would be.

Given the country's richness in solar resources, the technologies identified to provide off-grid services are solar lighting/charging products, solar home systems or diesel or hybrid mini-grids, although a throughout geospatial resource mapping of the country, completing the exercise started by GIZ, could reveal more renewable energy opportunities. For the Kano service zone, the costs associated to these technologies are in the range of US$50–100 for pico-solar, US$425 on average for solar home systems, and between US$500 to 1,2000 for mini-grids, depending on the service standard[5].

The costs associated to an off-grid programme will eventually depend on its size (that is, on the number of beneficiaries, their needs, and the technologies deployed) and are potentially substantial. For instance, given per- household SHS costs, the needs of the long-term off-grid beneficiaries could be met for around US$70 million. As regards pre-electrification purposes, the full rollout of the Tier 1 &2 programme could require around US$ 450 million alone (with an average combination of pico-solar and SHS solutions).

Notwithstanding its potential, the growth of the solar market in Nigeria is currently constrained. In fact, it is estimated that only 0.3 percent of households are using solar lighting products compared to 2–3 percent in countries such as Kenya, Tanzania and Ethiopia. Annual sales of solar lighting products are estimated at around 100,000 units, compared to 900,000 in Kenya. Two are the main factors that need to be tackled to support large scale off-grid developments: (i) lack of access to finance for importers, distributors and consumers and (ii) lack of an enabling policy and regulatory framework.[6] For the improvement of both the financial and the policy/regulatory dimensions, capacity strengthening support could be provided to sector stakeholders in the form of Technical Assistance.

A financing plan needs to be developed to support off-grid developments. The plan will have to be tailored to the current market structure and could envisage a combination of private sector and public sector-led programs and financing. International best practices can inform off-grid developments as well, and the establishment of a **line of credit** and/or a credit facility for the rollout of off-grid solutions has already proven to be very successful in countries such as Ethiopia and Bangladesh (described in Annex 6.4).[7] A line of credit could be opened to support DISCOs or small and medium sized private sector enterprises, and the facility/line of credit could either become integral part of the Electrification Fund suggested for the on-grid rollout or established separately. The financing mechanism can be designed to create a market-driven, private sector-led approach addressing some of the main issues preventing the off-grid market from taking off such as: access to finance at relatively lower cost of capital, access to foreign currency, and improvements to the general lending environment (e.g. fair-market collateral values), and identification of commercially viable delivery models.

On the public sector side, the FGN could build upon the National Renewable Energy and Energy Efficiency Policy adopted in April 2015 to develop an off-grid programme providing access to public institutions across the country. The National Policy was established to remove the key barriers that put renewable energy and energy efficiency at economic, regulatory or institutional disadvantages relative to other forms of energy in Nigeria. The policy states that PV power will be utilized to power low to medium power applications such as communication stations, water pumping and refrigerator in public facilities in remote areas and to extend modern energy service to rural and remote off-grid areas, through the use of solar home systems.

The successful implementation of a large-scale off-grid plan would also require providing a policy and regulatory enabling environment. In particular, institutional roles and responsibilities of sector institutions (e.g. Rural Electrification Agency, NERC and DISCOs) and stakeholders should be identified in the new market structure. Furthermore, rules governing the off-grid space, fostering market penetration and the coordination of private and public efforts, should be developed and enforced. This rules should include service standards for off-grid technologies, which may be differentiated for long-term and pre-electrification off-grid areas. Quality standards and warranties systems should be adopted for Tier 1&2 building on the best practices emerged internationally in this field, and for Tier 3+ grid compatibility should be ensured, not lastly to protect private investments. NERC should also be responsible for compiling a list of approved selected organizations. Subsidy frameworks could also be identified to ensure the scalability and affordability of the programme[8], particularly given the high cost of off-grid generation and current low penetration of off-grid solutions (support could be provided in the first phases for e.g. the marketing and distribution of products[9]). Problems of affordability of electrification that were described for grid-connected households will in fact be magnified in the off-grid space. The geospatial distribution of poverty reveals that the areas with high poverty risk are also the areas furthest form the existing grid, with the lowest population densities, and the highest cost of grid electrification. Hence, households that are expected to be connected in the later phases of the electrification rollout, or already targeted for off-grid solutions, are also mostly affected by poverty (see also Annex 2).

Although a specific rollout plan for off-grid will to some extent depend on KEDCO's determination to undertake a rollout plan in the next few years and its year-by-year geographic implementation and sequencing, this should not prevent the adoption of all of off-grid solutions. In fact, while the deployment of mini-grids may take longer, particularly in light of the absence of a regulatory framework (see Paragraph below), the distribution of pico-solar solutions and installation of SHS—supporting services up to general lighting, phone charging, and the use of a small television and a fan—should be firmly pursued.

The paragraphs below provide an overview of possible KEDCO-led as well as non-utility-led development of small grids isolated from the current distribution network that may supply consumers before they become connected to KEDCO's grid in the future.

6.1 The Current Regulatory Framework for Isolated Grids

Under Nigerian regulations, isolated grids (also known as mini-grids) are known as ***Independent Electricity Distribution Networks*** (IEDNs). They are currently regulated under the Nigerian Electricity Regulatory Commission (Independent Electricity Distribution Networks) Regulations, 2012, but we understand that these regulations are currently under review, with support from GIZ. At this stage, it is uncertain when revised regulations will be made available, but we anticipate this to happen sometime in early 2016. Some of the important provisions in the regulations are summarised in Annex 5.

At present, there is nothing in the regulations to guide the options for operators of isolated IEDNs when the DISCOs extend their network to within proximity of the IEDN. This question is a critical one in the context of the access expansion plan that is proposed, particularly if it is anticipated that private operators will be a key agent in developing IEDNs. In other countries, IEDN operators are comfortable with the approach of main grid networks, provided there is certainty over the timing of when the grid will arrive, and the operator's options when this happens.

We understand that the revised IEDN regulations will cover the options for IEDN operators when the main grid arrives. We also understand that the regulations will focus on systems between 100 kW and 1 MW.

6.2 DISCO-led Off-grid Electrification and Targeted Support

Although the main role of the DISCOs is to provide grid-based electrification services and electricity supply, they could have no role in providing electricity through isolated grids or, indeed, through off-grid options (pico-solar lighting, solar home systems). In many countries in Africa and elsewhere, the distribution companies also provide electricity through isolated grids (for example, Kenya, Malawi, Tanzania and Tunisia).

There should be no obstacles to KEDCO becoming involved in developing IEDNs and providing electricity services using off-grid solutions (solar home systems and solar pico-lighting). The utility should, in principle, be eligible under their existing licence to include the proposed costs of such investments in their projected Regulated Asset Bases and required revenues, and to recover the costs through tariffs. They might also consider establishing subsidiary companies with separate licences to allow greater flexibility in charging customers for these services.

Targeted support could be made for increasing electricity access through off-grid programmes. The power supplied by IEDNs and other off-grid technologies tends to be more expensive than that from main grids on a fully cost-reflective basis. If KEDCO (or indeed any operator) is able to charge tariffs higher than approved R1 levels for grid customers, it will need to consider both the cost to serve and the willingness of customers to pay. Tariffs cannot be greater than customers' willingness to pay, but if this level is lower than the full cost to serve, the operator will require a subsidy. This may be targeted towards one-off capital costs or recurring operating costs (the former is preferred for transparency and sustainability).

If and KEDCO management decides to be involved in off-grid developments, then it would have to include its cost in the tariffs and get NERC's approval. Following the principle that tariffs should be set at cost-recovery levels, tariffs for such off-grid customers would either need to be set higher than those for main grid customers, or alternatively, those customers on the main grid with relatively cheaper costs to serve could cross-subsidise those customers not connected to the grid.

The approach for cross-subsidisation could be either ***implicit*** or ***explicit***. An ***implicit*** approach would 'hide' the additional cost for the cross-subsidy within the tariff, where customers simply observe that they are charged the same tariffs regardless of their connection type. An ***explicit*** approach would set an additional amount in the tariff to cover off-grid customers, identified clearly on all main-grid customers' power bills. As either approach should achieve the same effect economically, the choice is perhaps more one of public or consumer acceptability.

6.3 Non-DISCO-led Off-grid Electrification

The DISCOs should not be barred from being involved in off-grid electrification, but at this juncture it would be counter-productive to make this mandatory. Off-grid electrification is likely to involve high costs and require a disproportionate allocation of management time, without a commensurate flow of revenue. These factors will discourage the KEDCO from becoming involved in off-grid electrification. One advantage of their doing so, however, would be providing scope for cross-subsidisation between higher-paying customers on the grid and the off-grid consumers. For this to become a significant feature of electrification in KEDCO coverage area, the cross-subsidy requirements would need to be analysed and explicitly incorporated in the MYTO calculations and approved by NERC.

To the extent that the KEDCO declines to take up off-grid electrification and publish plans showing communities without grid electricity for some time into the future, the Rural Electrification Boards (REBs) could take the lead in developing isolated mini-grids and solar home system programmes for these communities. Similarly, while traditionally the Rural Electrification Agency (REA) has focused on grid-based electrification, recognising that DISCOs will not be able to achieve full grid electrification by 2030, a better focus for the Agency would be on off-grid electrification (solar home systems, pico-solar lighting) and isolated grids in areas that are not expected to be grid-electrified in the near future.

Furthermore, while the approach for cross-subsidies between main grid and off-grid customers assumes a transfer within KEDCO's business, the principle may be applicable between the utility and a private operator, whereby KEDCO is required to collect tariffs that exceed its costs to serve particular customers in order that the surplus is transferred to reduce the cost to serve off-grid customers. In such an instance with different operators, it would be easier to collect and transfer the subsidy if it is explicitly itemised and collected in a customer's bill. This principle makes the economic outcome of off-grid supply indifferent to the system's ownership.

There may be scope for some local networks to be operated as small power distributors, with KEDCO merely providing the bulk power, and distribution, metering and billing being undertaken by the community or a local entrepreneur. As these local grids may later to be absorbed into the utility's distribution grid, appropriate regulatory arrangements need to be implemented to allow for a fair recovery of costs when this absorption takes place.

6.4 The Future Role of REA and REBs

The 2005 Electric Power Sector Reform Act established the Rural Electrification Agency (REA) and the associated Rural Electrification Fund (REF) and REA began operation in 2006. The law and associated policy documents outline the principles for rural electrification to:[10]

> *"Facilitate the provision of steady and reliable power supply at economic rates for residential, commercial, industrial and social activities in the rural and peri-urban areas of the country.*
>
> *Facilitate the extension of electricity to rural and peri-urban dwellers.*

Encourage and promote private sector participation in grid and off-grid rural development using the nation's abundant renewable energy sources while ensuring that Government Agencies, Co-operatives and Communities, participate adequately in enhancing electricity service delivery."

The Rural Electrification Agency's focus was on grid electrification based on funding from the Federal budget through the extension of existing grids to rural areas[11] (and handing over these networks to be operated by the then state-owned PHCN). Its current focus is the completion of around 2,000 electrification schemes that had begun but before 2009 but not completed. No information is currently available on the degree of their completion.

In the current new sector structure with privatized DISCOs, REA's old role is no longer operative and a new mandate and portfolio will have to be redefined at the FGN level. Recognising that DISCOs will not be able to achieve full grid electrification by 2030, a better focus of REA could be on off-grid electrification (solar home systems, pico-solar lighting) and isolated grids in areas that are not expected to be grid-electrified in the near future. When re-defining the role of REA in the off-grid space, careful attention will have to be paid to avoid any conflict of interest that could hamper the development of a competitive, transparent and vibrant market for off-grid solutions with the participation of the private sector.

Electrification targets and rollout plans, reviewed and cleared by NERC for each DISCO, will need to be published by the DISCOs and NERC to inform and guide the players of the off-grid space (potentially REA and REBs, but also independent electricity distribution network -IEDN- providers, private investors, and other off-grid providers and contractors) in choosing where to focus and align their efforts models, consistently with the updated energy access policy related to the off-grid institutional framework.[12]

The role and funding of state-level Rural Electrification Boards (REBs) will also have to be redefined in the new sectoral context by a new mandate at the FGN and State Government levels. The REBs have resources and capability to undertake grid electrification and could potentially reorganise themselves as contracting agencies able to compete with private sector contractors for electrification projects commissioned and paid for by the DISCOs. This would be a policy decision for the State Governments.

Endnotes

1. As noted by the geospatial report, these households and communities may, or may not, be far from the exiting grid, but their local isolation from neighboring structures raises the cost of grid connectivity greatly.
2. A Multi-Tier Framework for electricity access was developed by the World Bank Group under the Sustainable Energy for All (SE4All) engagement. The framework defines five different tiers of access for electricity supply corresponding to different electricity services is further discussed in Annex 4.
3. International experiences suggest that ~30% of the ~3.3. million identified as potential beneficiaries could be easily provided with access. World Bank Team Task Leaders estimates, 2016. For more information, visit: https://www.lightingafrica.org/.
4. International experience suggests that the market potential for this off-grid development is to date around 10% (i.e. 180,000 connections of the 1.8 million potential beneficiaries). World Bank Team Task Leaders estimates, 2016. The WBG Lighting Global recently started to operate in the Tier 3+ access delivery market.
5. The geospatial analysis identified the cost for a mini-grid with a service standard of 120 kWh/HH-year to be in the range of US$1,000-1,200 and for a 60 kWh/HH-year per customer service, between US$500 and US$700.
6. Lighting Nigeria also mentions as major obstacles for the development of an off-grid market: low levels of awareness of solar products, their advantages and ways to distinguish good quality products and low availability of products due to lack of distribution networks in rural areas.
7. The Bangladesh SHSs program has been widely acknowledged as the most successful national off-grid electrification program in the world reaching 100,000 installations a month.
8. Typically, for mini-grids, this implies grants to cover up to 80% or 90% of the capital costs.
9. Lighting Africa has supported the promotion of pico-solar lighting products to the base-of-the-pyramid households for a number of years but is no longer proposing direct subsidies the products. However, this kind of subsidies could also be considered.
10. This is extracted from the REA website.
11. This focus was described in a presentation by a Special Advisor to the Minister of Power during a Presidential Retreat in January 2012.
12. Discussed in Chapter 6.

Annexes

1 Summary of KEDCO Rapid Readiness Assessment

A Rapid Readiness Assessment was undertaken by the ECA team in October 2015 to understand the potential major barriers for delivering affordable and reliable electricity access, efficiently and sustainably nationwide. The assessment also considered the capacity strengthening initiatives needed to de-bottleneck an electrification access roll-out which are reflected in the proposed Technical Assistance activities outlined in the report. A summary of the findings is provided below.

The Readiness Assessment concluded that KEDCO, together with the DISCOs, will need to focus on stabilising its business and generating cash flow in order to establish a solid financial and electrical foundation for moving forward. For all DISCOs, expanded electrification access is not an immediate priority. Looking forward, with the right regulatory, commercial and incentive framework, expanded electrification access should be an attractive option for the companies to grow their business and expand their customer base. For this reason, the electrification programme discussed in Chapter 2 is assumed to commence in 2018.

Progress in sector reform: Major milestones for the implementation of the 2010 Power Sector Reform Roadmap and the establishment of a competitive market have been met. The unbundling and privatization of the vertically integrated sector utility, Power Holding Corporation of Nigeria (PHCN), was completed in November 2013[1] and the Nigerian Electricity Regulatory Commission (NERC) has been fulfilling its mandate of economic regulation including management of tariff reviews. The Nigerian Bulk Electricity Trader (NBET) was established to be the initial counter-party to bilateral contracts pending declaration of the TEM when the bilateral contracts between DISCOs and generation companies become effective.

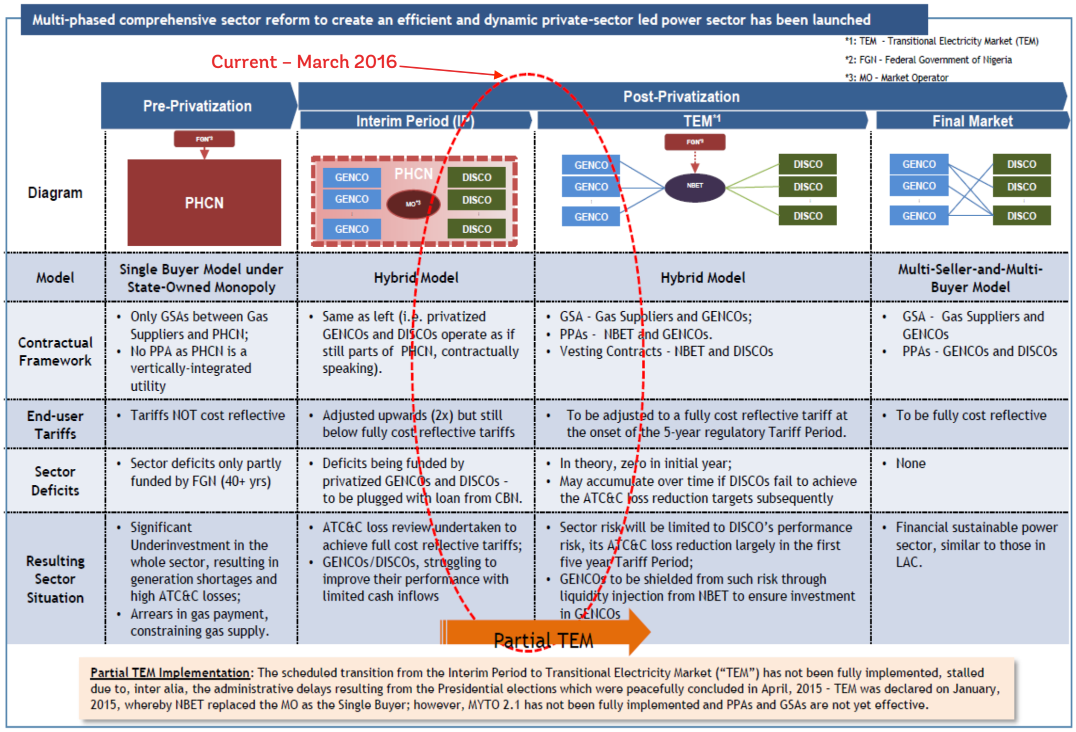
In February 2016, tariffs were re-set to cost-recovery levels (MYTO 2015), initially adopted in January 2015 but then reversed in April 2015. Following the adoption of cost-reflective tariffs in January 2015, the Performance Agreements (PA) and the Minimum Performance Targets (MPT) submitted at privatization came into effect.

Since cost-reflective tariffs were adopted two years after privatization, the MPT (ATC&C losses reduction, metering and new connections)[2] may need to be re-sculpted over the next 5 years and reflected accordingly in the business plans and in new targets. An assessment of the progress achieved by Discos since privatization (estimates of improvement in efficiency) could also be reflected in the new targets. Discos argue that there is also a need to reflect the removal of MDA non-payments from collection losses in the overall loss reduction targets. Negotiations between Discos and BPE are ongoing which is further delaying the implementation of measures to achieve the targets.

The adoption of MYTO 2015 shows progress in the assessment of ATC&C losses. Although bids were won on the basis of business plans for ATC&C losses reduction at the time of privatization an accurate assessment of losses was not available, hence tariffs were not adequately estimated. An agreement was then made between NERC and DISCOs to assess and validate the losses for their incorporation into MYTO 2.1 (January 2015). The validated losses for KEDCO were established at 48.7% (instead of the 40% indicated in the Business Plan). MYTO 2015 is based on the same set of validated losses with committed reductions starting in 2015.

The adoption of MYTO 2015 was meant to coincide with the activation of the Transitional Electricity Market (TEM), one of the pillars of the reform set out in the 2010 Roadmap to Sector Reform. TEM is the stage of market development which occurs after the activation of PPAs (with generation

Figure A1 Post-privatization market structure



Source: World Bank, 2016.

companies), GSAs (with gas suppliers) and vesting contracts (with distribution companies) thereby enabling full payments across the power sector value chain. Whilst it was originally envisaged that the TEM would be declared before or at the time of the completion of the privatization of the PHCN successor companies, its commencement had to be delayed until the adoption of cost-reflective retail tariffs. Following the implementation of the new tariffs, few conditions precedent remain before contracts can be activated (the most important being LCs provided by the Discos). The activation of the TEM will be a step forward in the contract-based market for electricity trade in Nigeria, essential for market discipline and for the financial viability of the electricity market. Furthermore, it is a step forward towards the ultimate goal of a robust competitive market where DISCOs will purchase directly from generation companies (without the need of a single buyer)—as set out in the Electric Power Sector Reform Act of 2005.

Although the tariffs have been raised to cost- and losses-reflective levels, the FGN decided to "sculpt" them to manage the increase for end-consumers, while DISCOs are expected to pay in full for the supply received. DISCOs will under-recover revenues in the first few years and over-recover later to have a fully cost-reflective outcome over a 10-year period (included into MYTO 2015). The FGN is expected to raise a bond and on-lend funds to Discos so as to enable them to make full payments up-stream from 2016 onwards. However, the timing and the size of the bond are uncertain, and DISCOs may be forced to fund the under-recovery from commercial banks. This could be problematic though as the deficit accumulated has surpassed their value at privatization (US $1.8 billion). The size of the under-recovery has been estimated at almost US$ 700 million in 2016 (16% of expected total revenue) for the whole sector, to be combined to the ~US$ 1 billion deficit accumulated in 2015 only (after the abandonment of MYTO 2.1 in April) and the ones accumulated from privatization until the end of 2014 (in the absence of cost-reflective tariffs) amounting to US$ 1 billion, for a total of almost US$ 3 billion owed by the DISCOs to the rest of the value chain by the end of 2016.[3] The losses accumulated until the end of 2014 are expected to be covered by the Nigerian Electricity Market Stabilization Fund (NEMSF) through loans provided by the Central Bank of Nigeria (CBN) but there is uncertainty about how the deficits for 2015 and 2016 onwards will be tackled.

Policy, institutional and regulatory framework: A policy, institutional and regulatory framework for expanded electrification access needs to be adopted with the inclusion of targets and timetables, funding mechanisms, and roles and mandated of sector institutions. The policy on electrification targets would need to be formally introduced by the Federal Government of Nigeria (FGN), with NERC responsible for implementing this policy by recognising the targets when approving the next multi-year tariff order (MYTO) and for approving the tariff designs in that Order. NERC will also be responsible for implementing the incentive framework to help ensure that the targets are met without damaging the commercial viability of the DISCOs.

The 2015 round of MYTO has not anticipated major electrification investment expenditures. Although MYTO is set for ten years and is normally reviewed every five years, there are provisions for earlier reviews. Such a review should be undertaken ahead of an electrification programme commencing in 2018. Given the need time needed to properly develop a new MYTO and the importance of ensuring that the DISCOs are creditworthy and able to attract commercial financing for their normal business, the review should begin early in 2017.

Financial readiness: Since privatization until the end of 2015, KEDCO itself has accumulated US$140 million in debts owed upstream for the supply[4] received and has received US$38 million in 2015 from the Nigeria Electricity Market Stabilization Fund (NEMSF) as loans funded by the Central Bank of Nigeria (CBN) to pay upstream debtors. KEDCO currently has negative cash flows and as shown by Figure A2 below, it is currently able to meet an average of only 40% of payment obligations to the bulk trader (NBET).

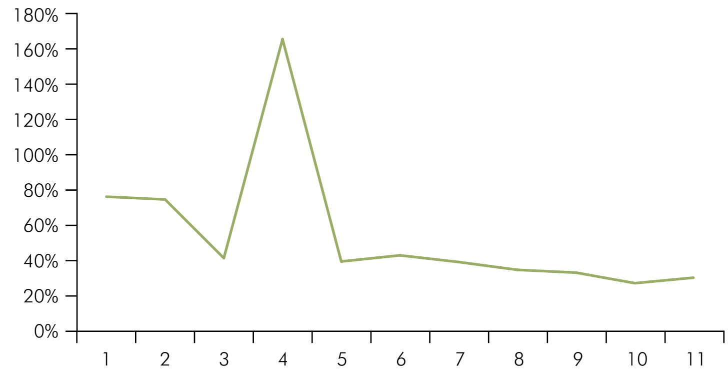
Because of the "sculpting" introduced with MYTO 2015, KEDCO is expected to have cost-reflective tariffs (with no under-recovery) by the start of 2018 and it will hence keep accumulating deficits until then.[5]

Like the other DISCOs, KEDCO's financial position is also worsened by the removal of fixed charges form MYTO 2015 and of MDAs debts, which in the case of KEDCO account for 3% of the ATC&C losses,[6] without the introduction of a mechanism for defrayal. In addition, MYTO 2015 was based on optimism in the tariff review process over the power supply figures (of 5,000MW whereas a more realistic figure would have been 4,000MW–4,500MW), further decreased by recent militant pipeline attacks in the producing zones of the country. In 2015, total available supply was of 3,500MW and in the first quarter of 2016 of 3,150MW. Estimates foresee an average (for the whole sector) increase in tariff by 50% (including forex)[7] to reflect the new available supply conditions, which is likely not going to be approved by NERC.[8]

The newly approved MYTO 2015, covering the period to 2024, made no provision for electrification investment and, because of the "sculpting", tariffs are currently not covering for all operational costs. The companies urgently need to make other investments including metering, management and billing systems, and rehabilitation and upgrade of existing networks and these will have a higher priority than expanded electrification. Although a bottom-up assessment of progress in loss reduction and efficiency since privatization is not available for KEDCO nor for other utilities, it is worth noting that the only known significant loss reduction capital expenditure made by KEDCO was the purchase of 64,000 meters from the proceeds of the CBN NEMSF at the beginning of 2016.

During the last round of tariff revision, DISCOs lamented the insufficient capex to meet the Minimum Performance Targets contained in the Performance Agreements, but NERC didn't allow for

Figure A2 KEDCO payment of NBET invoices (Feb–Dec 2015)



Source: World Bank, 2016.

an increase. In MYTO 2015 the capex allowance was actually decreased by 20% and in the case of KEDCO capex fell from US$ 23.5 million to US$ 19 million per year. NERC's decision was based on the fact that DISCOs had not made use of the capex allowance they've had so far. This is because in an environment where tariffs were non-cost-reflective, DISCOs were unable to justify the borrowing needed to fund capital expenditure and therefore to implement their business plans and invest in metering and other loss reduction activities. DISCOs are allowed to file for upward revisions if and when they are able to prove that they have sufficient funding sources for planned capital expenditure.

Technical readiness of KEDCO and the supply chain: three main issues will have to be tackled in order to embark in an extensive access program (i) business planning (ii) revenue collection (iii) infrastructure building.

(i) *Business planning*

KEDCO needs to improve its business planning capacity as Business Plan submitted at privatization by KEDCO presents some numeric inconsistencies and leads to confusion in the actual values for the Minimum Performance Targets. DISCOs also need to harmonize future investments with current expenditure.

The business plan submitted at privatization was not based on sound estimates of ATC&C losses and the meter deployment targets didn't reflect a realistic price for meters. The average price of meter estimated was of about $25, which compares low with the current price range of $160–220 (as indicated by the geospatial analysis and as per discussions with KEDCO), even when taking into account that the utility now plans to deploy smart meters only.

Sound planning should to be based on a bottom-up assessment of the utility's investment needs. The geospatial analysis revealed that in order to achieve the Minimum Performance Target of 100% metering, KEDCO will have to deploy about 1.5 million meters in the next five years, a target that is 35% bigger than the one contained in the Business Plan submitted at privatization, which envisaged the deployment of 512,164 meters.

The Minimum Performance Target on new connections indicated KEDCO's plans to connect about 350,000 new customers. However, as per discussions with the utility, the majority is targeted households were already consumers that needed to be regularized and not access provision to un-electrified households. Planning should therefore also carefully make the distinction between new connections and regularized ones.

(ii) *Revenue collection*

The majority of KEDCO's ATC&C 49% losses are due to collection issues (responsible for about 37% of ATC&C losses).[9] KEDCO needs to implement an aggressive meter deployment rollout and build the capacity to support new metered connections. The Business Plan does not contain plans for metering lifeline (R1) costumers, whereas it is key that this category is also included to ensure billing of actual energy consumption over time and hence track migrations toward an upward consumption category, particularly since R1 costumers are expected to be the majority of new connections in the access program.

With the adoption of MYTO 2015 in February 2016, and the removal of fixed charges and MDAs debts from the tariffs without a mechanism for defrayal, and the rejection by NERC of a further diversification of the R2 category, the liquidity and collection pressure has become even greater. Given the negative implementation record of the Credit Advance Payment for Metering Initiative (CAPMI),[10] KEDCO should either build the capacity in-house or rely on trustworthy vendors.

(iii) *Infrastructure building*

KEDCO has limited experience of extending electricity grids on any scale, and it has limited human, material and technical resources for undertaking a major programme of connecting customers through intensification or grid extension. It accepts that to a large extent the electrification work will need to be contracted out to the private sector.

KEDCO will need capacity building to be able to supervise and manage a major electrification programme.

The private sector in NW Nigeria is experienced in undertaking electrification works, though not on the scale necessary to achieve the electrification rollout needed for KEDCO.

Kano has a strong manufacturing base and it has private companies that manufacture poles, overhead line steelwork and conductors for the electricity sector. It also has private contractors who undertake electricity distribution works (procurement and construction)[11] typically working in NW Nigeria. The economy in the NW of Nigeria has been undermined by security problems in recent years and the private sector currently has underutilised resources.[12] An electrification programme would help boost the economy and increase utilisation of staff and equipment of manufacturers and contractors. Some distribution equipment is imported (e.g. transformers). This is normally procured by KEDCO and by private construction companies on the open market but Nigeria often faces bottlenecks at the ports and customs and this will inevitably result in some bottlenecks that will impact the electrification programme at times. This is a chronic problem in Nigeria.

Private contractors typically provide in-house training for linesmen, fitters, jointers, etc. The Industrial Training Fund (ITF) is used for training engineers and technicians for more complex equipment and processes. In the electricity sector, training is provided by the National Power Training Institute of Nigeria (NAPTIN). NAPTIN was formerly part of PHCN but is currently owned by FGN and provides a range of training services under contract to the electricity companies. It has a training facility on the outskirts of Kano city that provides training for the electricity companies in the north-west of Nigeria. This facility is equipped with modern equipment. It does not currently provide training in the skills needed for the expansion of the distribution network (linesmen, fitters, jointers, etc.) but it has space on the site to allow such training if requested by the DISCOs or the private sector. Support for the expansion of this facility would be valuable in enabling the roll-out of the electrification programme in the KEDCO service zone (and potentially also in Kaduna service zone). The training facility might also provide training suited to the development of isolated grids.

Wholesale generation adequacy: There is currently insufficient generation to meet consumer demand. Wholesale generation is generally rationed to the DISCOs with KEDCO being allocated 8% of electricity available. Since privatisation, the availability of existing generation plants has improved substantially and the supply to DISCOs has increased[13] but generation shortages and load shedding remain chronic. Furthermore, recent pipeline vandalism attacks brought the available power supply from 3500MW in 2015 to 3150MW at the beginning of 2016, a value below 2014 levels (3300MW). In 2015, KEDCO only received 5% of the allocated supply.

New generation projects in the pipeline are the FGN sponsored National Integrated Power Projects (NIPP) originally launched in 2005. The first private sector power plant reached financial closure in December 2015 (Azura-Edo, part of a 2,000 MW IPP).[14]

The framework for attracting private investment in power generation exists (specifically, the wholesale tariffs available for generators are attractive) and guarantees are available, and it must be assumed that in time there will be adequate generation capacity to satisfy the growing demand. The conservative electrification plan for KEDCO described in Chapter 2 in the main report is based around a relatively slow initial electrification rate that allows generation capacity to catch up with demand over the next five or so years. The electrification plan anticipates a relatively modest additional 30 MW arising because of the electrification programme by 2020 and 128 MW by 2023. In the best-practice electrification scenario, an estimated additional 60 MW of demand is anticipated by 2020, and 257 MW by 2023 and the geospatial analysis revealed that by 2030, about 1 GW will be needed to support the rollout plan.

Transmission adequacy: The transmission system to the KEDCO franchise area has a transfer capability constrained to less than 250 MW. The maximum demand that has actually been supplied was 286 MW. Because of the transmission constraint, KEDCO is not able to take its full 8% allocation of generation from the wholesale market. A series of transmission investments have been prioritised by the Transmission Company of Nigeria (TCN) to relax the transmission constraints on the supply to KEDCO and to improve supply reliability. As with generation capacity, it must be assumed that transmission investments will be made and that the transmission network will be adequate to allow supply to match demand in the KEDCO zone. Again, the gradualist electrification programme described in Chapter 2[15] with the first connections beginning in 2018 and growing slowly at first will allow time for the transmission investments to be made.

Endnotes

1. With the exception of Kaduna, which was privatized in 2014.
2. Discussions with KEDCO revealed that the for new connections the utility intended for the most part to regularize exiting ones.
3. World Bank estimates, June 2016.
4. World Bank estimates, March 2016.

5. World Bank estimates based on the MYTO model, March 2016.
6. According to Energy Markets and Rates Consultants (EMRC), formerly Mercados EMI, a consultancy providing advisory services to Nigerian DISCOs.
7. World Bank estimates, May 2016.
8. A further increase in tariffs would also trigger public discontent.
9. The baseline of losses integrated into the new MYTO 2015 reports 37.4% of collection losses, 6.8% of commercial and 13.5% of technical losses. Note that the aggregate ATC&C losses of 48.7% is not additive but it is defined by a formula.
10. The Minister of Power, Works and Housing requested NERC to stop the CAPMI scheme in April 2016 because meters were not being deployed.
11. Their main clients were the REBs but this work has partially fallen away following privatisation. There is ongoing work with the local government and for isolated schemes.
12. We understand that some factories used for manufacturing poles and conductors are temporarily closed but could be re-opened at relatively short notice.
13. Some DISCOs are said to be rejecting load. It is believed that, despite high demand, it costs DISCOs more than they earn in revenues on electricity sold to some consumer groups. This is largely because of the high commercial, technical and collection losses and low tariffs. With the tariff increase in February 2016 this situation may no longer be true.
14. The facility is expected to produce 450 MW in the first phase, and then increase production up to 2,000 MW. The commissioning was supported by guarantees from the World Bank Group and construction started in January 2016. For more information, visit: www.azurawa.com.
15. Both the conservative and best-practice programme build up gradually, though the conservative scenario has a slower take-off.

2 Customer Income, Expenditure and Affordability

The analysis of affordability reviewed the available datasets to inform the access rollout program and ensure that shared prosperity across the country is pursued during the design and implementation of the programme.

Current expenditure in energy (whether electricity or alternative sources, such as kerosene, battery lamps, etc.) can be used to assess people's ability to pay for electricity. Table A1 provides a summary of the average level of household expenditure on energy and a measure of how these values of average expenditure translate into kWh per month at the standard residential tariff.[1]

The measures of expenditure above, despite their limitations, provide similar results on the average level of expenditure of households (about ***2,000 NGN per household per month***, equating to ***an average consumption of 83 kWh***).

The following sub-sections provide additional details on the distribution of expenditure among potential electricity customers, and the affordability of electricity prices.

2.1 Income and expenditure distribution

Table A2 shows the level of expenditure in NW Nigeria for income quintiles, broken down by type of expenditure.[2]

More detailed figures from the distribution of the broader category *Expenditure on non-food non-durable goods* of the General Household Survey (GHS) proxies for the distribution of the average expenditure in energy goods reported by Lighting Africa and NIAF (of about 2,000 NGN/HH/month).[3] The results of this are shown in Figure A3.

At the standard residential tariff for KEDCO (R2 tariff – see Section 5.1) for 2020, 50 kWh would cost a household NGN 938 (US$ 4.69) per month.[4] The above implies that 49% of the population normally pay less than NGN 938 per month on electricity-type energy consumption. From a policy perspective, it suggests that 49% of the population may not be able to pay for electricity at the standard tariff. It also suggests that 15% of the population may not even be able to afford the lifeline tariff of only NGN 4/kWh (US$0.02).

Table A1 Current expenditure on energy

Reported average expenditure (NGN/HH/mo)	Equivalent in kWh/month at the R2 tariff[a]	Source	Scope and limitations
1,773	69	General Household Survey (GHS), wave 2, post-harvest dataset (2012–2013), LSMS	Average for NW region, includes all types of energy (for lighting, cooking, transportation, etc.), but excluding batteries and phone charging (which, unfortunately, may be the most relevant substitues of electricity.
2,258[b] 2,375[c]	107	Lighting Africa Nigeria Insights Study, August 2013	Limited to Kano state, mainly Base of Pyramid population domiciled in rural and urban locations (without electricity) – includes expenditure on rechargeable lamps, kerosene and petrol genstes. Does not include phone charging.
1,989	83	NIAF surveys	Surveys in 3 rural villages in Jigawa state. Average expenditure in battery lamps, kerosene and phone charging.

Sources: General Household Survey, Lighting Africa, and Nigeria Infrastructure Advisory Facility.
[a] At KEDCO's current tariff for R2 customers – see above.
[b] Variable.
[c] Total, including cost of purchase of device (e.g. lamp, genset).

Table A2 Expenditure in NGN/month

Quintile	Total expenditure[a]	Expenditure on non-food non-durable goods	Durable goods	Energy expenditure[b]
0–20	10,876	683	374	0
20–40	16,625	1,749	813	400
40–60	23,050	3,355	1,386	1,200
60–80	35,049	6,342	2,483	2,400
80–100	331,114	243,343	33,300	61,000
Average	**27,238**	**5,089**	**1,744**	**1,773**

Source: General Household Survey.
[a] Includes food, other non-durable goods, and durable goods.
[b] Includes goods and services that are not strictly relevant to this analysis, as they will unlikely be replaced by electricity (e.g. petrol used in transportation, firewood and charcoal used for cooking).

2.2 Geographical distribution

Figure 7 shows the poverty rate (% of poor households) for the KEDCO service area based on research from Oxford University on behalf of the World Bank. This is based on geostatistical modelling using geospatial covariates that are correlated with poverty (e.g. travel times, population density, aridity, night lights, etc.). The report indicates a poverty headcount at the state level of 45% for Kano, 57% for Jigawa and 57% for Katsina. The poverty data was used by the Earth Institute to classify households as having a potential demand for electricity of 50 kWh per month or 100 kWh per month.

Figure A4 highlights that there are areas without poverty (the dark blue areas) around the cities of Kano and Katsina with low incidence of poverty. Elsewhere there are areas with high incidence of poverty, particularly in Katsina and Jigawa.

Endnotes

1. KEDCO data for R2 customers, May 2015, shows an average of NGN 22.8/kWh but this includes a fixed charge of NGN 667/month and a price per kWh of NGN 16.01.
2. The questionnaire omitted expenditure on batteries (disposable dry-cell batteries or battery charging, including phone charging), which are significant to this analysis
3. This excludes cost of buying appliances (lamps, gensets)
4. 50 kWh at NGN 16.01 per kWh plus NGN 667 per month comes to NGN 1,467.

Figure A3 Estimated distribution of relevant energy expenditure

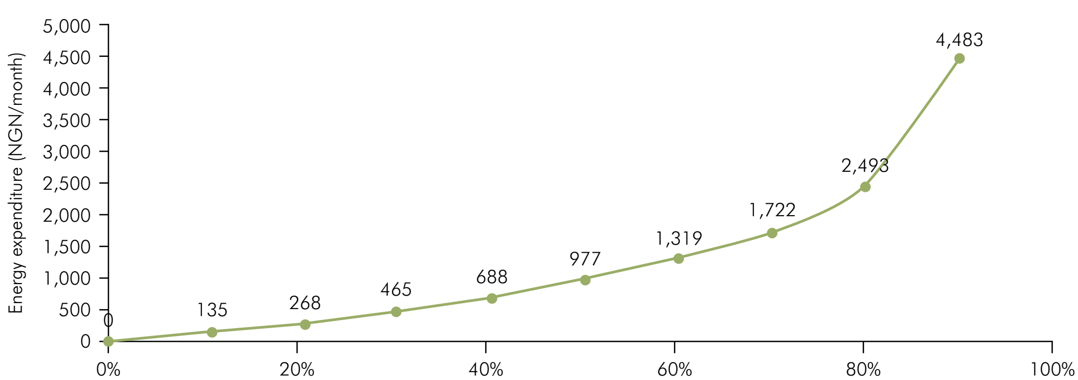
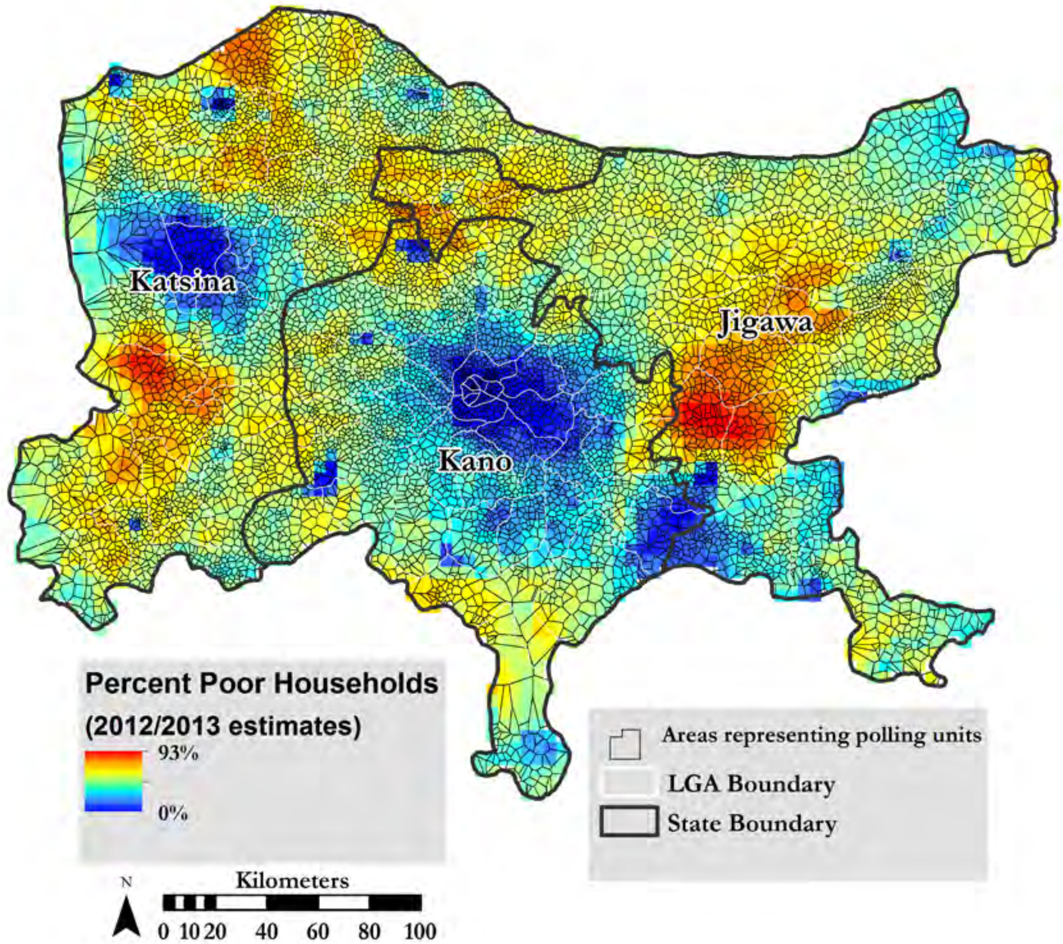


Figure A4 Poverty rate (% of poor households) for the KEDCO service area



Source: Nigeria Electricity Access Program (NEAP*) based on geospatial data from Oxford University (Gething & Molini).
* Final Report, Geospatial Implementation Plan for Grid and Off-Grid Rollout (2015-2030), Earth Institute, October 2015.

3 Estimation of Cross-subsidy to R1 Customers

3.1 The tariff regulatory framework

The regulatory framework determining electricity revenues and tariffs is set out in the 2005 law[1] and the tariff regulations have been developed by NERC using a building-blocks model to establish the allowed revenues and tariffs on a multi-year basis. Allowed revenues for the DISCOs are calculated on the basis of operating costs including depreciation on fixed assets plus rate of return on net fixed assets plus pass-through of elements such as the bulk purchase tariff and the fees for TCN, NBET and NERC. At the start of the control period, the tariffs are fixed for the duration of the control period (with periodic adjustments for the non-controllable components) and the DISCOs are expected to manage their costs efficiently. If they can make above average profits by being cost-efficient, they are allowed to keep the profits and the shareholders receive good dividends but if DISCOs are inefficient, they make low profits and the shareholders receive no or low dividends.

In theory, if the capex programme implied by the electrification programme is reflected in the allowed revenue calculations used to design the MYTO tariffs, and if the tariffs are affordable, then customer revenues would be sufficient to allow the DISCOs to make a respectable return on their investment and to service their debts and no further subsidy would be required. However, there is currently no allowance for an electrification programme in MYTO 2015 and the tariff is not covering in full for operating costs.

3.2 Tariff design limited to the current R1 and R2 categories

Annex 2.1 noted that large proportions of the population of NW Nigeria could not afford the conventional R2 tariff.[2] We therefore assume that 70% of households will initially be connected as R1 customers but that on average they will migrate to the R2 tariff after 5 years.[3] In this sub-section we consider the potential consequences of connecting large numbers of R1 customers through the electrification programme.

We model a connection scenario to determine the total requirement for cross-subsidy to new R1 connections, with the following assumptions:

- KEDCO serves approximately 70,000 R1 customers at the present time
- 70% of the additional 3.7 million customers added by 2030 through intensification and grid extension will be connected as R1 customers
- These customers will remain as R1 customers, with consumption at 50 kWh per month for the foreseeable future
- KEDCO's cost to serve R1 customers is the same as the cost to supply the average customer.[4]
- The difference between KEDCO's average tariff and the R1 tariff is the required cross-subsidy.

Following these assumptions, we forecast that the value of cross-subsidies required will increase steadily, reaching **NGN 15 billion per year (US$ 77 million)** in 2030. This is a relatively large amount compared with KEDCO's annual revenues today (approximately US$100 million billed, but significantly less collected), but by 2030 this will represent a much smaller share of the total. While the cross-subsidy amount steadily increases in absolute terms, the number of non-R1 customers and their electricity consumption also increases steadily, thereby increasing the base across which the cross-subsidy can be collected. We calculate that the incremental amount needed on top of the average cost-recovery tariff to meet the cross-subsidy will rise to **NGN 0.7/kWh** by 2030 (US$ 0.003/kWh) or around 4% of KEDCO's commercial end-user tariff. Initially, however, the increase would be more modest at around NGN 0.2/kWh in 2020.

The above assumes that consumption of non R1 customers grows at 10% per year, allowing a large base of consumption from which to collect the cross-subsidy.

While from the utility's perspective, KEDCO should recover all costs at the aggregate level and be provided with sufficient revenue to earn a reasonable rate of return on capital investment, it will be able to make higher profits by avoiding the connection of customers at the R1 tariff. When the maximum tariff the DISCO can earn from R1 customers is only NGN 4/kWh and the cost of supply is over NGN 20/kWh, KEDCO will lose money on every unit sold at the R1 tariff. A profit-maximising company will therefore naturally attempt to avoid R1 customers. Therefore, it will be necessary to place some obligations on the DISCOs to connect and supply these customers. This is discussed further in Chapter 5 of the Report.

3.3 KEDCO's proposed R2-lite and R2-classic categories

As KEDCO observed in its tariff submission to NERC, there is a large difference in monthly bills between an R1 and an R2 customer. A household using 50 kWh on the R1 tariff will pay NGN 200 per month, while a household also using 50 kWh on the R2 tariff in 2016 will pay NGN 1,013 per month.[5] There will therefore be a large deterrent to customers using more than 50 kWh per month because of the step increase in their monthly electricity bill. Table 23 in Annex 2 shows that the conventional R2 tariff is affordable by less than half of the population whereas the R1 tariff is affordable by more than 85%.

The R2-lite tariff proposed by KEDCO to NERC in its tariff submission offered an intermediate step between R1 and R2-classic that makes the step less expensive, though still quite substantial. Unfortunately, this was rejected by NERC.

Endnotes

1. Electric Power Sector Reform Act, 2005.
2. Though it is not reflective of the costs of supplying residential customers, it is the closest approximation available.
3. This is an assumption. KEDCO has relatively few R1 customers compared with R2 and it is therefore likely that customers relatively quickly exceed 50 kWh per month.
4. This assumption is incorrect since the cost to supply residential customers is greater than the cost to supply all other customers, but it is a first approximation.
5. This is based on KEDCO's approved R2 tariff for 2016.

4 Transitional Electrification Options

4.1 Choices

The main choices for pre-grid electrification are isolated mini-grids, SHS and pico-solar lighting products. The choice between these options depends on how long it will be until the main grid arrives, population densities, load densities and capital constraints. The choice is discussed further in Annex 4.3. Pico-solar lighting products are ideal for bridging the gap in the short-term until power arrives; this can be for a period of a year up to perhaps three years. Even after the grid arrives, these products will still have value in providing lighting and battery charging during power cuts from the main grid. If the main grid is not expected to arrive within five years, but is expected between five and ten, then a mini-grid could provide a transitional arrangement. If the main grid is not expected for many years because the population is highly dispersed, distributed solar will be the preferred solution in this case.

The regulation governing IEDNs (see Section 6.1) will be revised and will hopefully introduce a framework that makes it attractive to develop isolated grids[1] even where they may be engulfed by the KEDCO grid in the foreseeable future. Assuming this is the case, the optimum policy on electrification technology is then determined by economic principles and financing constraints. This recognises that electrification based on isolated grids and distributed solar may face fewer financing constraints than grid electrification provided that the framework is appropriate.[2]

A decision tree for this calculation is provided in Figure 9 in Annex 4.3.

4.2 Electrification to target poverty

The geospatial distribution of poverty is described in Annex 2.2. Further analysis of the geospatial data through correlation analysis reveals that the areas with high poverty risk are the areas furthest from the existing grid and with the lower population densities and the highest costs of grid electrification, and therefore these are the areas least likely to be connected to the KEDCO grid early in the electrification programme. This suggests that programmes designed to support off-grid electrification will have important social dimensions because these are also likely to be areas with high poverty.

Our approach to solutions for the off-grid component of the programme is built around electrification access 'tiers'[3] whereby electricity access is not simply defined by reference to a grid connection or not, but is graduated through tiers 1 to 5 where tier 1 households have access to simple low wattage lighting (solar, rechargeable batteries or conventional batteries) and phone recharging through to tier 5 where households have access to a reasonably high quality, continuous, and reliable electricity supply that is capable of powering significant electrical appliances such as electric irons, fridges and TVs. The tiers have multiple attributes of capacity (W or kW), duration (hours/day), reliability (interruptions per week), quality (stable voltage), legality (a formal connection, or an informal or illegal one) and safety (see A5 below).

We assume that 'un-electrified' households will have access to pico-solar lighting (and battery charging) solutions through local markets. Consideration could be given to supporting this group of products perhaps in areas where market penetration is low—particularly to areas where poverty levels are greatest. Support need not necessarily be provided through subsidies to the product itself, though this is an option, but potentially through support to the marketing and distribution channels for pico-solar lighting. Lighting Africa has supported the promotion of pico-solar lighting products to the base-of-the-pyramid households for a number of years but is no longer proposing direct subsidies for the products. Pico-solar lighting is an excellent short-term product providing lighting and mobile phone charging until more substantive solutions can be introduced. We assume this is the solution to be adopted for those households who will remain 'un-electrified'. The Lighting Africa Market Study[4] conducted in 12 Nigerian states including Kano, found that the majority of households were aware of pico-solar lighting products. We could not find information from the survey on the penetration of solar in the market in the KEDCO zone or in NW Nigeria in general, but the publicly available findings indicate some reservations, particularly among urban households, around the limitations of pico-solar lighting products.

4.3 Off-grid electrification strategies

Below we consider the choice between pre-electrification strategies:

- wait and do nothing
- distributed solar (SHS and pico-solar), or
- isolated mini-grids

Figure A5 Multi-tier matrix for access to household electricity supply

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
1. Capacity	Power[1]		Very Low Power Min 3 W	Low Power Min 50 W	Medium Power Min 200 W	High Power Min 800 W	Very High Power Min 2 kW
	AND Daily Capacity		Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
	OR Services		Lighting of 1,000 lmhrs per day and phone charging	Electrical lighting, air circulation, television, and phone charging are possible			
2. Duration	Hours per day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
	Hours per evening		Min 1 hrs	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
3. Reliability						Max 14 disruptions per week	Max 3 disruptions per week of total duration < 2 hours
4. Quality						Voltage problems do not affect the use of desired appliances	
5. Affordability					Cost of a standard consumption package of 365 kWh per annum is less than 5% of household income		
6. Legality						Bill is paid to the utility, prepaid card seller, or authorized representative	
7. Health and Safety						Absence of past accidents and perception of high risk in the future	

Source: ESMAP[a].
[a] Beyond Connections: Energy Access Redefined, Conceptualization Report, ESMAP, June 2015.

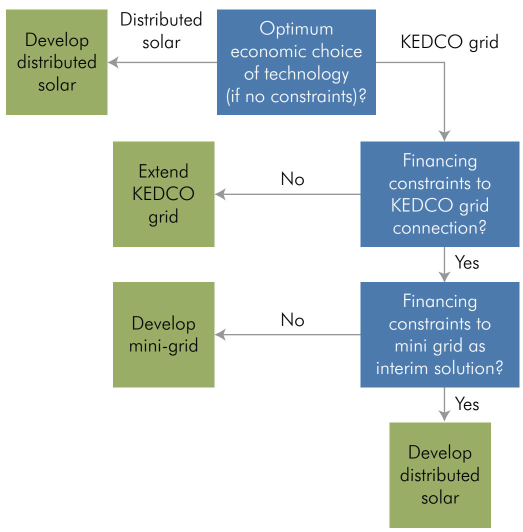
We cannot offer a precise time criteria to decide when to choose between do nothing, distributed solar (SHS or pico-solar) or mini-grids. The mini-grid is a more expensive transitional solution but if the mini-grid can be incorporated into the main grid, the investment will not be lost when the main grid arrives. It is a trade-off between having no power for, say, five years versus introducing a more expensive mini-grid in, say, one year. This requires a complex economic cost-benefit analysis, possibly on a case-by-case basis.

An example of a study in India that attempted to provide a systematic basis for choosing was undertaken in India and published in Energy Policy: *A techno-economic comparison of rural electrification based on solar home systems and PV microgrids.*[5] However, the primary focus was the choice between grid electrification and isolated grids rather than a pre-grid electrification programme. Moreover, costs of solar PV have declined substantially since 2010 and the rule-of-thumb parameters would need to be updated.

Off-grid electrification involving SHS and pico-solar lighting products has a relatively low capital cost but the equipment has relatively short lives. Pico-solar lighting solutions in particular are cheap and have a life of only perhaps 5 years because of the current battery technologies, and this makes them particularly suited as interim solutions for bridging the gap until power arrives; this can be for a period of a year up to perhaps three years. Even after the grid arrives, they will still have value in providing lighting and battery charging during power cuts from the main grid.

SHS have higher capital costs than pico-solar lighting and longer economic lives. For areas that do not currently have electricity but are expected to be electrified within a few years, investment in SHS could incur relatively high capital costs (compared with pico-solar lighting) that may be largely wasted

Figure A6 Decision tree for non-KEDCO grid electrification



once the grid arrives. They may have some residual value when the grid arrives as backup for grid interruptions or to supplement the supply from the grid or potentially they could be recycled for use in other areas.[6] However, SHS may also be suited to more remote areas with low population and load densities for whom the geospatial analysis reveals that neither grid connection nor isolated mini-grids are economically justified at least not within the time horizon of 2030.

Investment in isolated grids in areas that will be connected in a few years' time will not be wasted if those isolated grids can simply be connected into the main grid when it arrives. The generation plants used to supply the isolated grids could, when the isolated grid is connected to the main grid, be relocated to other isolated areas or alternatively they could be used to inject power into the main grid and/or support the network in that area.[7] These generation investments will not then be wasted though if relocation takes place this will incur some cost (relocation will not in any case be possible for some technologies such as small hydro).

From the perspective of optimum economic policy, the choice of interim technologies for areas that will eventually be connected to the KEDCO grid is therefore complex. One way to approach this is to categorise areas as in Namibia's off-grid masterplan[8] with one category called "pre-grid areas". These are expected to be electrified within five years. In Namibia these were excluded from the off-grid masterplan except where there were delays in grid electrification. In Kenya, an area that is not expected to be electrified within 10 years was considered suited to off-grid electrification (but because of the absence of a grid roll-out plan, a criterion of 50 km distance from the main grid was also adopted as an alternative).

Population densities in Nigeria are generally higher than in Kenya and Namibia and grid coverage is very widespread so that few households are far from the existing grid. The rule-of-thumb policies in Kenya and Namibia ignore the benefits of developing isolated grids using grid technical standards that can then be absorbed into the main grid and fully compensated by KEDCO, or kept as small-power distributors (SPDs) and purchase electricity wholesale from KEDCO.

Endnotes

1. i.e., financial compensation from KEDCO to the grid developer following takeover by KEDCO or the conversion of the isolated grid to a small power distributor (SPD), plus a feed-in tariff for renewable energy purchased from the generator.
2. Experience in Cambodia is relevant here. Electrification initially took place successfully with a large number of isolated grids that are now being connected to the main grid as the main extends further outwards. The isolated grids may be connected as SPDs or may be fully absorbed into the main grid.
3. *Beyond Connections: Energy Access Redefined, Conceptualization Report*, ESMAP, June 2015.
4. Lighting Africa, *Nigeria Consumer Insights Market Study*, 2013.
5. A. Chaurey, T.C.Kandpa, *A techno-economic comparison of rural electrification based on solar home systems and PV microgrids,* Energy Policy, 38(2010)3118–3129.
6. Though experience elsewhere suggests that the re-use value of SHS is relatively low because of rapid technological development and the deterioration in the batteries and other equipment.
7. Solar plants that are suitably designed can be relocated. Small hydro can be used to inject power into the existing grid.
8. Off-grid energisation masterplan for Namibia, January 2007.

5 Independent Electricity Distribution Networks

Under Nigerian regulations, isolated grids (also known as mini-grids) are known as ***Independent Electricity Distribution Networks*** (IEDNs). They are currently regulated under the Nigerian Electricity Regulatory Commission (Independent Electricity Distribution Networks) Regulations, 2012, but we understand that these regulations are currently under review, with support from GIZ. At this stage, it is uncertain when revised regulations will be made available, but we anticipate this to happen sometime in early 2016.

Some important characteristics of an IEDN under current regulations:

- May be developed, owned and/or operated by a DISCO or other entity
- Include both purely isolated systems and those connected to existing DISCO networks
- May have their own embedded generation source, or purchase power from the DISCO operating the network to which it is connected
- Allowed to operate within a DISCO's concession area, provided there is no other distribution system 'within the geographical area'
- [Must be at least 5 MW]

The regulations currently allow and/or require:

- Cost-reflective tariffs
- Meeting 'relevant Technical Codes and standards'
- Compliance with the System Operator's requirements (if connected to the main grid)
- Provide non-discriminatory open access to its distribution system by any other Licensee, if it has the capacity to do so
- No increase charges to accommodate losses above the MYTO limit
- Meter any new customers
- Apply the connection charge approved by NERC[1]
- Meet voltage standards based on the capacity of the generation in the system

In addition, a relevant reference in the Electric Power Sector Reform Act, 2005, states:

- Distribution systems with capacity under 100 kW do not require a license

Endnotes

1. Currently NERC does not approve connection charges for residential customers.

6 Examples of International Experience

Nigeria is unusual in Africa, though not unique, in having privatised electricity distribution companies. The expansion of electricity access through electricity grids in developing countries is typically handled by state-owned companies or through agencies created for the primary purpose of electrification. However, international experience suggests that expansion of access to electricity can be effective in countries where electricity distribution is privatised. A report prepared by IFC[1] notes that:

> *A rigorous 2009 study looked at data on 250 electricity companies across 50 countries.[2] The study found that utilities that had been privatized, or which operate under PPPs, extended access more rapidly than publicly owned utilities.*

> The IFC report also notes that:

> *Almost all examples of grid-based electrification business models have involved a PPP with some degree of capital subsidy to attract private investment. Governments have most often awarded contracts with legally binding coverage targets and quality-of-service requirements. This sometimes comes with public financing to help cover the cost of such obligations. This subsidy is most often allocated on the basis of the lowest-cost but highest-quality service offering, and is applied to cover the viability gap on capital but not operating costs.*

International experience therefore offers some useful lessons for the expansion of electricity in Nigeria. An example of Brazil is provided below. Other examples of countries that have combined substantially increased electricity access with private electricity supply include Chile and India.

6.1 Brazil

Brazil, like Nigeria, has a large population (approximately 190 million) and a Federal and State administrative structure. By 2009 Brazil had reached an overall electrification rate of 98% achieved largely through grid extension. Electricity distribution is mainly privately operated through geographically based concession arrangements. The Ministry of Mines and Energy (MME) is the policy making entity for the power sector and the companies are regulated by the Electricity Regulatory Agency (ANEEL).

Until the 1990s, rural electrification policies were implemented largely at the State level, using State budgetary resources. Electrification programmes had been introduced during the 1970s, 1980s, 1990s and early 2000s but the discussion below focuses on the last programme that was began in 2003—the Luz para Todos (Light for All, or LpT), which achieved virtual universal access to electricity by 2010.

LpT is based on an obligation for concessionaires to provide universal electricity access using substantial federal and state resources channelled to the companies, and on low electricity tariffs for low-income and rural consumers.

Lpt was to provide 2 million new rural connections, subsequently revised to 3 million, over a five year period to 2008. Each household was also to receive power plugs, lamps, and other necessary material needed to undertake the internal wiring and lighting. The deadline was later extended to 2010.

ANEEL (the regulator) set and verified the annual electrification targets for the companies while Eletrobrás (the Federally-owned holding company owning a large part of the generation plant and the transmission grid) managed the electrification programme including carrying out the technical and financial analyses of the connections to be installed by the companies and the allocation of funds to the companies and the monitoring to ensure the claimed installations had been made. MME co-ordinated the LpT programme and set the policies governing it.

The LpT programme mainly targeted those living in the northern and north-eastern states where electricity access at the beginning of the programme was lowest. These two regions accounted for more than 75% of the planned installations.

The overall cost of LpT was around US$ 7 billion (original estimates were US$ 4.2 billion). It was funded largely by Federal and State governments in the form of grants and concessionary loans to the concessionaires. The State governments' contributions averaged 13% of the total capital costs while the Federal government was the main source of funding (72%) through Global Reversion Reserve (RGR) which provided grants and concessionary loans. RGR is funded by annual levies on the concessionaires supplemented by funds from various other sources (payments for the use of public assets, fines received by ANEEL). The concessionaires' equity participation in financing the electrification was around 15% of the capital cost. No connection charges were levied on rural consumers. Operating costs for rural consumers were to be covered by the utilities through general electricity tariffs. The tariffs were subsidised for consumers with low consumption. Around 35% of all consumers have low consumption and benefit from subsidised tariffs. These represent an even higher proportion in rural areas.

6.1.1 *Key lessons learned*

- Rural electrification access, whether undertaken by the private sector or the public sector, will need substantial external financial support.
- Widened electrification access can go hand-in-hand with privatised distribution.
- Electrification targets need to be set for the distribution concessionaires.
- A framework is needed to monitor the connection of rural households and to disburse funds based on verified connections of designated consumers.

6.1.2 *Information sources*

- *Comparative Study on Rural Electrification Policies in Emerging Economies, Keys to successful policies, IEA, Alexandra Niez, 2010.*

6.2 Chile

Chile has a long history of rural electrification as local cooperatives were formed as early as the 1930s to support agricultural development. The national distribution companies were split up and privatised in the 1980s but did not hold an exclusive right to serve customers. Electrification rates increased gradually under private ownership and in 1990 rural coverage reached just under 50% of households. The Chile Rural Electrification Program (PER) aimed at increasing rural electrification was implemented in 1994 and was supposed to increase rural electrification coverage from 50% to 75% by the year 2000. The program offered governmental subsidies to private entities in order to incentivise rural electrification. PER was given sufficient authority to develop and guide the policy initiative and long-term governmental goals were established. A strict project selection method was created and built on top of the already stable private distribution companies and cooperatives. The goal of 75% electrification was reached in 1999 and due to the program's success a goal of 90% electrification by the year 2005 was set.

The project selection methodology ruled out all projects which were assumed to have a positive IRR as it provided sufficient incentive for the private market to develop. The selection method accounted for economic benefits of electrification within the region and projects and utilities rated based on the lowest subsidy required per user. In some cases, this created a competition among the private utilities to find innovative ways of reducing operational costs to receive the contract. This helped lower the cost of rural electrification in some areas. In others, where no competition existed, the private utility sometimes deliberately adopted assumptions designed to increase potential profit. As a response, PER adopted standard measures, based on local data, for subsidy calculations.

The aid offered by PER was constructed in a way to help utilities during the first stages of implementation, and then decrease with time. Due to Chile's long history with private utilities, a clear set of rules and standards for infrastructure was already in place. This eased the transition into subsidised rural electrification projects as most problems and disputes could be resolved by referring to standards and precedents. The Chilean National Energy Commission (CNE) was the central entity responsible for the design of PER and allocation of funds to regional governments who then allocated them on a project basis.

6.2.1 *Key lessons learned*

The need for a clear and transparent project assessment methodology is vital to this type of a program. It limits political and commercial influence on the program and makes sure projects are ranked on the basis of merit.

Governmental support is very important to the credibility of a program. CNE's role in PER was vital as it provided a leadership and monitoring role while maintaining authority within the regional governments. CNE built enough public and political momentum for the program to continue across administrations and shifts in Chile's political landscape.

By adopting construction and material standards, construction costs can be kept at a minimum.

6.2.2 *Information sources*

- *Integrated Transmission Planning and Regulation Project: Review of System Planning and Delivery*, Electric Policy Research Group, Imperial College London/University of Cambridge, 2013
- *Challenges of power transmission expansion in a fast growing country*, Prof. Hugh Rudnick, Pontificia Universidad Católica de Chile, Workshop on International Experience in Transmission Planning and Delivery, Imperial College, London, 11–12th January 2013
- *Market Based Transmission Planning: Chilean Experience*, Juan Carlos Araneda, Transelec, Work-

shop on Transmission Network Security Standards, Imperial College London, March 9th, 2009

- *Electricity distribution tariffs, the Chilean Experience*, Hugh Rudnick, Pontifícia Universidad Católica de Chile, International Seminar on Electricity Tariffs, Brazil, June 2009
- *International transmission pricing review*, Frontier Economics, a Report prepared for the New Zealand Electricity Commission, July 2009

6.3 India

India has the largest rural population in the world, totalling 876 million people in 2014, making rural electrification a major challenge. One of the major barriers to rural electrification expansion has been a general lack of electricity generating capacity in India. Technical and commercial electricity losses also rank among the highest in the world and have acted as a barrier to electrification.

The Electricity Act of 2003 compelled the utilities to supply electricity to all households, including rural areas. The National Electrification Policy of 2005, the Rural Electrification Policy of 2006, and the National Tariff Policy of 2006, were all designed to encourage rural electrification efforts. Additionally, they improved the financial and institutional status of the state utilities, generation, transmission, and distribution. This included unbundling state utilities, widening the scope for state government action in rural electrification efforts. The Electricity Act of 2003 also increased competition by giving the private sector access to all power sector operations, including investing in rural electrification projects. Administrative mechanisms were established to allow for the private setup of decentralised generation projects and stand-alone systems.

Institutional and regulatory reforms undertaken over the past 15 years have included unbundling the State Electricity Boards (SEBs), increasing private sector involvement in generation, transmission, and distribution, and looser rules on electricity tariffs. These reforms also initiated the "Power for all by 2012" goal, which aimed to ensure sufficient power to achieve GDP growth targets, reliability, quality, optimum costs, and commercial viability.

Rural electrification accelerated under the 11th Five-Year Plan (ending March 2012), which provided both political will and funds. The Plan allocated US$241 billion for electricity including, with US$65 billion for generation and US$30 billion for transmission and distribution for rural areas. Two electrification programmes began in 2005: the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) scheme and the Remote Village Electrification (RVE) programme. The latter focused on off-grid electrification and non-grid solutions. The RGGVY scheme was aimed at grid electrification and is the focus of this case study.

6.3.1 *Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) scheme*

Launched under the "Power for all by 2012" initiative, the RGGVY programme involved a major grid extension and reinforcement of rural electricity infrastructure. The primary approach was through grid extension, with stand-alone systems if grid extensions were not feasible.

The policy initially aimed to provide electricity access for all households (an additional 87 million households) by 2009 in the without subsidy for households above the poverty line, but the rollout was slow and was extended. Only 30% of household connections and 51% of villages targeted under the initial plan had been achieved by 2009. The main reason for the delay was the high technical and commercial losses in India's rural distribution network, which meant that utilities were disinclined make rural electrification connections.

As the RGGVY programme was refined, the central and state governments were given joint responsibility for rural electrification, with state governments required to prepare rural electrification plans that outlined methods and electrification technologies. Plans were then coordinated across state governments and utilities by the Rural Electrification Corporation Limited (REC).

90% of funding was provided by the central Ministry of Power (MoP), with state governments covering the rest through their own funds or loans through the REC or other institutions. State governments were then responsible for implementation through their state power utilities, with the MoP directing the states to establish Coordination Committees to track progress and identify issues. Milestone-based monitoring mechanisms were put in place from project approval to completion, including a web-based monitoring system at the village level, and with the release of funds being dependent on milestones being met. Independent, random evaluations were also used to verify the connections claimed. MoP noted that progress in rural electrification projects improved with these mechanisms in place.

By 2012, India had reached an urban electrification rate of 93%, but only 53% for rural areas, bringing an overall electrification rate of 65%. As of 2015, India claimed 97% of villages were electrified, but a more stringent definition of rural electrification based on households connected would lower this rate to approximately 70%.

6.3.2 *Key lessons learned*

High levels of losses and poor revenue collection is a significant barrier to enhanced electricity access.

Notwithstanding the privatised distribution companies in India, there is a need for state funding of electrification access.

It is possible to adopt different technical standards for different states.

Use of milestone-based monitoring improved rural electrification progress, with the release of funds made dependent on states reaching milestones

6.3.3 *Information sources*

Information derived largely from Comparative Study on Rural Electrification Policies in Emerging Economies, Keys to successful policies, IEA, Alexandra Niez, 2010.

6.4 Off-grid developments: Bangladesh and Ethiopia

The Bangladesh SHS program has been widely acknowledged as the most successful national off-grid electrification program in the world. Since its inception, more than 3 million SHSs have been installed, two-thirds of which in the last 3 years and reaching 100,000 installations a month. The programme was developed under The Rural Electrification and Renewable Energy Development World Bank project.

The programme is managed by Infrastructure Development Company Limited (IDCOL), a semi-governmental infrastructure finance organization, which works through a pool of partnering microfinance institutions and it demonstrates the feasibility of having beneficiaries pay for a substantial portion of the SHS asset in affordable instalments (quality standards are vetted by a technical standard committee).

SHS systems are affordable through a combination of consumer credit/refinancing and (declining) subsidies. The idea was to bring monthly expenditures as close as possible to existing household spending on kerosene and dry cells. Partner organizations provide microfinance loans to households, who are required to make a down payment equivalent to 10–15 percent of the cost of the system. The remainder is repaid in 2–3 years at prevailing market interest rates (typically 12–15 percent). Sixty to eighty percent of the credit that the partner organization extends to the household is eligible for refinancing from IDCOL at the prevailing market interest rate of 6–9 percent, with a 5/7-year repayment period and a 1–1.5-year grace period. Partnering organizations are responsible for collecting payments, providing maintenance, and training customers in both operation and maintenance. Beneficiaries are given a buy-back guarantee with the option of selling their system back to IDCOL at a depreciated price if a grid connection is obtained within a year of purchase, however most customers have preferred to hold on their solar system as grid supply remains unreliable.

The World Bank Electricity Network Reinforcement and Expansion Project (ENREP)

The Electricity Network Reinforcement and Expansion Project (ENREP), approved in 2012, targets the private sector-led development of stand-alone renewable energy and energy efficient products in Ethiopia. The design of the financing mechanism creates a market-driven, private sector-led approach and addresses the following main issues to enhance the market for renewable energy in Ethiopia: access to finance at relatively lower cost of capital, access to foreign currency, and improvements to the general lending environment (e.g. fair-market collateral values).

As a result, ENREP's design entails a US$20 million credit line (as a Financial Intermediary Loan) for renewable energy and energy efficiency products administered by the Development Bank of Ethiopia (DBE). The credit line has two main elements: retail lending to private sector enterprises and whole sale lending to the microfinance institutions. There are no limitations placed on the technologies/products being supported, so long as they are of approved quality standards (e.g. Lighting Global).

To date, ENREP's credit line has been a huge boost to Private Sector Enterprises and has resulted in the local sale of almost 250,000 (15,000 targeted by the project) Lighting Africa quality verified solar portable lanterns, is on track surpass 2 million products by the end of 2016, and provided 750,000 people with access to modern energy services.

Endnotes

1. *From Gap to Opportunity: Business Models for Scaling-up Energy Access*; IFC, undated, probably 2012. p.111.
2. *Does Private Sector Participation Improve Performance in Electricity and Water Utilities?* Gassner, Popov, and Pushak, World Bank, 2009.

WORLD BANK GROUP
1818 H Street, NW
Washington, DC 20433
USA
Telephone: +1 202 473 1000
Internet: www.worldbank.org