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Over the past two decades, the world has made tremendous progress towards the United Nations' sustainable development goal (SDG) number seven, namely, access to affordable and clean energy.[1] Multilaterals such as the World Bank and the African Development Bank spend billions of dollars each year in efforts to achieve SDG-7's goal of universal access, which has enabled millions of households across the world to get connected to the electricity grid.

One country that has actively pursued nationwide mass electrification in recent years is Kenya. In a May 2015 Presidential Address, Kenya's president Uhuru Kenyatta announced the Last Mile Connectivity Project (LMCP).[2] The goal was for Kenya Power, the country's majority government-owned electric utility, to connect all Kenyan households to electricity by 2022. While these ambitious goals were not met, Kenya Power did make significant progress: electricity access rates were reported to have increased from 25% in 2009 to 70% in 2019.[3]

The implementation of infrastructure projects is often outsourced to private sector firms. These large construction contracts are often worth thousands, if not millions, of dollars. What types of contracting structures can governments and multilateral agencies use to improve the quality and timeliness of infrastructure construction progress, while also minimizing costs? This is the question we try to answer in a new research paper, "Contracting Structures in Public Procurement: Evidence from Donor-Funded Kenyan Electrification."[4] This policy brief summarizes our paper.

Electricity in Kenya

There are around 60,000 electrical transformers across Kenya, which convert high- and medium voltage power lines to low voltage power lines that can connect households to the grid. In rural areas, many transformers were constructed as part of the Rural Electrification Authority's Strategic Plan 2008-2013, implemented between 2008–2013.[5] This plan included a push to connect key public facilities in rural areas—such as health centers, secondary schools, and markets—to electricity. As a result, such transformers are often located in villages where

[1] "Goal 7: Ensure Access to Affordable, Reliable, Sustainable and Modern Energy for All," United Nations, https://sdgs.un.org/goals/goal7.
[2] "Cost of Electricity Connections Reduced to Sh15,000," *Business Daily Africa* (May 27, 2015), https://www.businessdailyafrica.com/bd/economy/-cost-of-electricity-connections-reduced-to-sh15-000-2088204.
[3] "2009 Kenya Population and Housing Census." Kenya National Bureau of Statistics. https://statistics.knbs.or.ke/nada/index.php/catalog/68.
[4] Catherine D. Wolfram et al., "Contracting Structures in Public Procurement: Evidence from Donor-Funded Electrification in Kenya," Working Paper (June 2023), https://sberkouwer.github.io/WMHB_donorprocurement.pdf.
[5] "Strategic Plan from 2008-2012." Rural Electrification and Renewable Energy Corporation. https://www.rerec.co.ke/StrategicPlan.php.

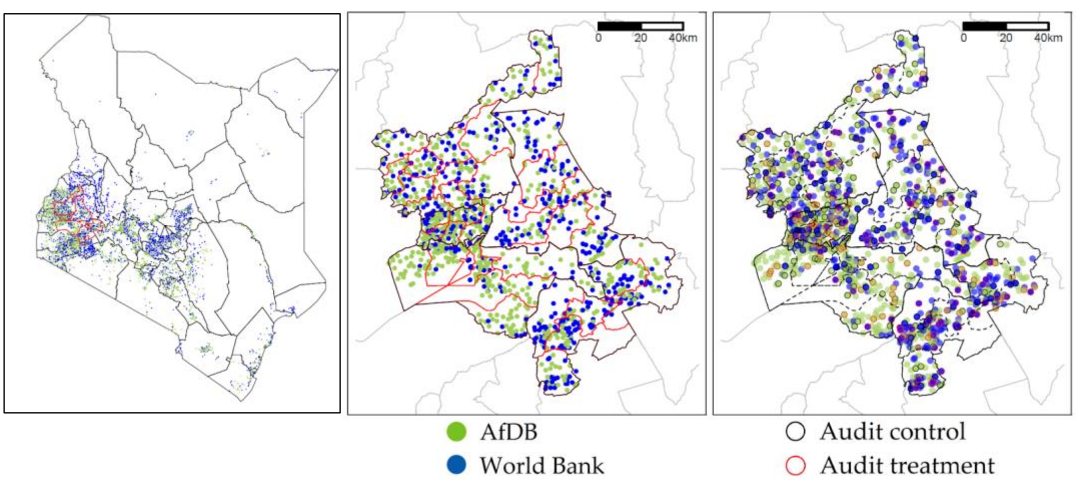
very few households were connected at the start of LMCP. Kenya Power in consultation with the Ministry of Energy and members of parliament selected 8,520 such transformers for the LMCP, targeting an equitable regional distribution across Kenya.

The objective of the LMCP was to connect all unconnected households located within 600 meters of an LMCP transformer by extending the local LV network. At most LMCP sites, between 20 and 100 unconnected households were eligible. Connecting all unconnected households in a village at the same time—referred to as ‘maximization’—was intended to generate cost efficiencies by leveraging economies of scale. Eligible households benefited from a reduced electricity connection price, from the previous \$350 down to \$150, as well as from the ability to pay it off in monthly installments, with no upfront down-payment.

To complete construction at the 8,520 LMCP villages, Kenya Power awarded dozens of private sector contracts to procure goods and services. These contracts were financed, in part, by the World Bank (WB) and the African Development Bank (AfDB): the AfDB financed the maximization of 5,320 of the LMCP transformers and the WB financed the maximization of 3,200, with both sets of transformers located across the country. Panel A of Figure 1 shows the locations of all the WB and AfDB sites across Kenya, confirming that both sets of sites were distributed nationwide and were often quite close to one another. Our research focuses on a specific region where there was especially significant overlap between WB and AfDB sites, framed in Panel B: the five counties of Kakamega, Kericho, Kisumu, Nandi, and Vihiga.

Figure 1: Locations of Last Mile Connectivity Project villages across Kenya

Panel A: Nationwide | Panel B: Survey region | Panel C: Audit treatment



Note: Panel A plots LMCP sites that were funded by the WB and AfDB Phase I across all of Kenya. Panel B zooms in on the sites in the five study counties (Kakamega, Kericho, Kisumu, Nandi, Vihiga). Panel C shows the random assignment to an audit treatment.

Incentivizing high-quality construction is complicated, as policymakers and funders often do not have perfect insights into the private actions of contractors. Many projects seek to achieve high quality by implementing regulations or procedures, or by conducting inspections and making payment conditional on satisfactory performance. The WB and the AfDB do use such procedures—but interestingly, there were two key differences between the procedures that Kenya Power used at the two sets of sites. The first was the contracting structure, and the second were the ex post inspections.

Two Different Procurement Procedures

The first difference between the procedures used for WB-funded sites versus AfDB-funded sites is the level of contract bundling. Contracts for AfDB-funded sites covered activities to produce designs, supply materials such as poles and cables, and install all materials on site. In contrast, WB-funded sites had separate contracts for designs, various materials, and installation services. Table 1 describes the differences between the two approaches in greater detail. Which method is preferred? There is very little research on the real-world consequences of using these different contracting structures. A recent chapter on "Procurement Choices and Infrastructure Costs" in a volume released by the National Bureau of Economic Research found that "it is still not fully clear whether contracts that bundle the design-and-build phase outperform the traditional design-bid-build contract, where the two phases are procured separately."[6]

Table 1: Two Distinct Contracting Structures

Bundled contracting ("turn-key" or "design-and-build")	**Unbundled contracting ("design-bid-build")**
For LMCP sites funded by the AfDB, Kenya Power awarded 10 sets of identical, "turn-key" contracts (also referred to as 'design-and-build' in some contexts). Each of the ten turn-key contracts comprised the entire construction process of all LMCP transformers in a region. This process included designing an efficient extension of the LV network to reach unconnected households, procuring the necessary materials, and final installation of these materials.	For LMCP sites funded by the World Bank, Kenya Power used an unbundled contracting approach. Eight contracts were first issued for designs detailing the proposed LV network extensions across eight sets of sites. Kenya Power then issued 15 separate contracts to procure materials: six for wooden poles, three for concrete poles, three for conductors, and three for cables. Finally, it issued six different contracts for installation at all LMCP sites located in one of six geographic clusters of counties. Kenya Power also included two metering contracts and four consulting contracts, for a total of 35 contracts funded by the WB.

[6] Dejan Makovšek and Adrian Bridge, "Procurement Choices and Infrastructure Costs," in Edward Glaeser and James Poterba, eds., *Economic Analysis and Infrastructure Investment* 277-327 (2021).

The second difference between the procedures that Kenya Power used for contractors at the two different types of sites is that the WB required Kenya Power to complete an additional inspection report after the contractor completed construction. While implementing more rigorous post-construction inspections costs time and money, it could lead to improved construction outcomes. To understand the impact of such an ex-post inspection, we implemented a randomized controlled trial. Panel C of Figure 1 shows which sites were in the control and treatment groups. Members of our research team met with contractors in person to inform them of the randomly selected subset of treatment sites, which we tell them will be audited after construction. Given that the WB procedures already included a round of ex post audits, we would expect this additional round of audits to have a larger impact at AfDB sites than at WB sites.

How do the two contracting structures affect the quality, timeliness, and costs of construction? One key fact that enabled us to answer this question is that LMCP sites funded by the WB and AfDB sites were both interspersed across the country: 95% of WB sites are within 10 km of an AfDB site, and vice-versa. This made it very unlikely that there were going to be big geographic, economic, or social differences that might otherwise cause differences between construction at the two sets of sites. Any difference we observe should be due to the differences in contracting procedures.

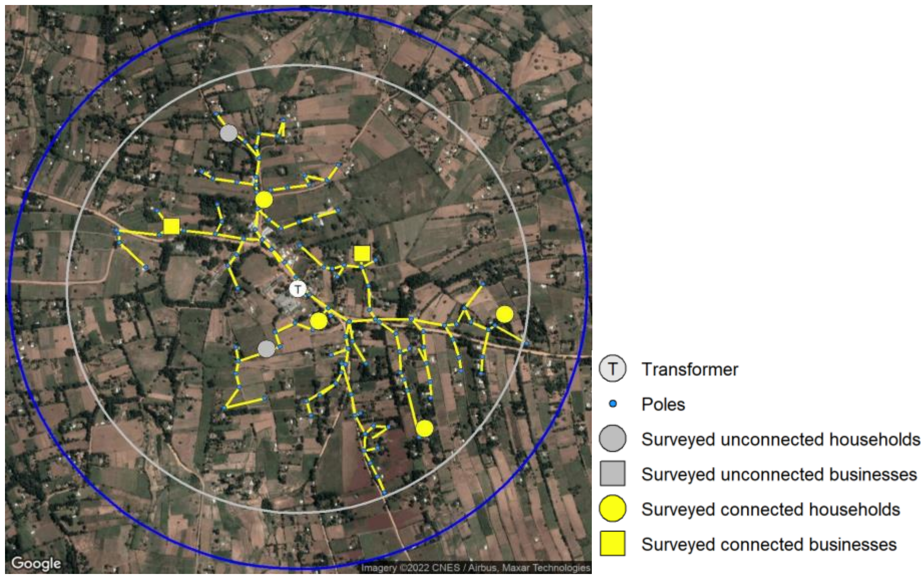
Collecting On-the-Ground Data on Construction, Household Experience, and Power Quality

Between 2016-2023 our research team conducted dozens of qualitative interviews with senior leadership at Kenya Power, the WB, the AfDB, as well as some of the contracting companies. In addition, we analyzed valuable administrative data that Kenya Power provided us through a data sharing agreement that was signed in 2017. For example, we examined the original contracts signed between Kenya Power and contractors to observe the timelines and costs.

However, a key complication when studying a project such as this is that while administrative data can be valuable, if the data are generated by the funding agencies or contractors themselves, they may not be reliable. Our research team therefore set out to collect our own primary data. To understand how the procedural differences affect construction outcomes on the ground, we collected data on 380 LMCP villages. Panel B of Figure 1 zooms in on this region.

As we could only conduct surveys once construction at a site had been completed, we began by reaching out to village representatives and asking them about any electricity grid construction activities they may have observed. By the end of surveying activities in July 2022, construction had been completed (or almost completed) at 250 out of the 380 sites. For these 250 sites, surveying teams spent one full day at each site. They first collected GPS and engineering quality measurements of transformers, poles, and wires, as well as accessories like struts and stays. They then conducted between 3-6 household surveys on connection cost, timing, and experience. Figure 2 shows an example of the data collected at a site.

Figure 2: Example of a Last Mile Connectivity Project (LMCP) Village



Note: Each LMCP site is centered around a transformer from which low-voltage wiring extends to connect households and businesses to the grid. The gray circle denotes the 600m eligibility radius and the blue circle denotes our 700m surveying threshold.

In addition to the infrastructure measurement and household survey data, we also deployed nLine's PowerWatch devices with 600 households across 150 sites. Each PowerWatch device measures voltage and power outages on a minute-by-minute basis, providing geographically and temporally high-resolution insights into not just access to the grid, but also the quality of that connection as actually experienced by households.[7]

Figure 3: A PowerWatch Device

Note: Each household is compensated for keeping a PowerWatch device plugged in in their home for two months. PowerWatch devices are designed, managed, and analyzed by nLine Inc.

[7] nLine. https://nline.io.

In addition to these primary data, we analyzed:

- 2009 Census data, land gradient data, and HERE Maps travel data to confirm that there are no other differences between WB and AfDB sites before construction.[8]
- VIIRS nighttime radiance data to confirm that the data reported to us on the phone by the village representatives matches when villages first received electricity.[9]

Results

The analysis of the data identified three main results:

1. First, the flexibility afforded to contractors through turn-key contracts generated several improvements at AfDB-funded sites. Households in villages funded by the AfDB are connected to electricity on average 8 months sooner than households in villages funded by the WB. This delay is caused primarily by the increased bureaucratic requirements resulting from the larger number and heterogeneity in WB contracts, as well as poor coordination between the various stages of WB contracting. More poles and household connections were also constructed at AfDB sites, driven in part by the WB's stricter adherence to the rule that only households within 600 m of the transformer were to be connected.
2. Second, the unbundled contracting approach and more rigorous inspections used at WB sites, while taking longer, does generate tangible benefits: on-the-ground construction quality is 0.6 standard deviations higher at WB sites than AfDB sites, driven largely by the increased presence of pole caps, stays/struts, and grounding wires. While this does not lead to any improvements in voltage quality or power outages in the short term, these improvements are likely to improve grid longevity, lowering long-term maintenance and replacement costs.
3. The additional audit treatment improved construction quality at AfDB sites but not at WB sites. These results hold across three different outcomes: the audit treatment increases the number of poles constructed at AfDB sites (but not at WB sites), improves average voltage by 5V at AfDB sites (but not at WB sites), and improves household installation quality and electricity usage at AfDB sites (but not at WB sites). Taken together, these results suggest that the additional inspection prescribed by WB procedures has an important effect on construction quality. The impact of the audits at AfDB sites but not at WB sites could be because the WB already saw an additional round of inspections, or because the monitoring has more bite when conducted for turn-key contractors. Either way, more rigorous ex post audits offer a way to increase quality at relatively low cost and with few delays.

[8] Kenya National Bureau of Statistics, *supra* note 3; "U.S Releases Enhanced Shuttle Land Elevation Data." NASA Jet Propulsion Laboratory. https://www2.jpl.nasa.gov/srtm/; "HERE Developer." HERE. https://developer.here.com/.
[9] "Visible Infrared Imaging Radiometer Suite (VIIRS)." NASA Earth Data. https://www.earthdata.nasa.gov/learn/find-data/near-real-time/viirs.

Conclusion: Informing Future Electrification and Other Infrastructure Projects

When awarding major contracts for the construction of electricity networks and other large scale infrastructure projects, which contracting approach is preferred? Evaluating the relative net benefits of the two approaches requires understanding the long- and short-term costs and benefits. On the one hand, WB procedures delayed the household connection date. This may be especially costly if the value of an electricity connection is high (as this means the cost of waiting longer is also high). On the other hand, by improving the quality of construction WB procedures will likely reduce long-term maintenance costs when compared with AfDB procedures. We calculate that even a reasonable set of assumptions indicate anywhere from a USD 5.6mn net benefit of AfDB processes to a USD 2.8mn net benefit of WB processes. Neither method is necessarily the best option, and the optimal contracting structure will depend on the project's goals and the government's priorities (Table 2).

Table 2: When Might a Policymaker Prefer Different Contracting Structures?

Bundled contracting ("turn-key" or "design-and-build")	Unbundled contracting ("design-bid-build")
● When policymakers are able to instead implement stricter auditing, as this can improve quality at lower cost and with fewer delays ● When policymakers have a shorter time horizon and want to prioritize timely completion ● When rapid urbanization reduces the value of the investment in the long run ● When policymakers have less information about the quality of local suppliers than the firms to which they may award turn-key contracts	● When policymakers have a longer time horizon and want to prioritize infrastructure resilience ● When policymakers expect long-term grid maintenance costs and replacement costs to be a big concern in the future ● When policymakers expect users to highly value infrastructure quality and reliability. For example, if energy-intensive businesses are expected to connect and they require reliable power to operate.