

Issue BRIEF

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Grid Electricity Expansion in Tanzania: Findings from a Rigorous Impact Evaluation



MCC energy sector project

The Millennium Challenge Corporation (MCC) funded a large energy sector project in Tanzania between 2008 and 2013. The investment was made in part because electrification was seen as key for economic development and because few households in Tanzania were connected to the national grid. Only about 18 percent of households in mainland Tanzania were connected to the grid in 2011–2012, and the rate was under 4 percent in rural areas (NBS 2014).

Rural electrification in Tanzania has been slow because of the high cost of extending the national grid throughout the country. Indeed, it may take decades before the grid reaches the majority of Tanzanians (Ondraczek 2013). Recognizing the importance of electricity for economic development, the Tanzanian government plans to increase electrification rates to 50 percent by 2020 and to 75 percent by 2035 (IED 2014).

MCC's energy sector project was designed to promote economic growth and curb poverty in Tanzania and was implemented by a Tanzanian government entity called the Millennium Challenge Account–Tanzania (MCA-T). One component of that project involved building new lines to the electrical grid. To address the concern that connection fees were a barrier to connecting to those lines, MCC also funded a second component that offered low-cost connections to households in a subset of the communities getting new lines.

This issue brief summarizes findings from the final evaluation report on impacts of these two components of the energy sector project on a variety of outcomes for households and businesses in the communities where these interventions were implemented. To estimate impacts of line extensions, we used a difference-in-differences approach, comparing outcomes of households in communities that were and were not selected to get new lines funded by MCC (Figure 1). To estimate impacts of the low-cost-connection offers, we used a group randomized controlled trial, comparing outcomes of households in communities randomly selected to get the low-cost offers and new lines with outcomes of households in communities selected to only get the lines. The box on the following page provides a brief summary of the components and the evaluation design we used to estimate their impacts. Our evaluations of the line extensions and low-cost-connection offers help us assess the degree to which these components of the energy sector project succeeded in achieving the goals of MCC and the Tanzanian government. Because connection rates remained low, we also present estimated impacts of actually connecting to help policymakers assess the potential benefits of line extensions under higher connection rates than those found here.

Our key research questions for the evaluation include:

- What are the impacts of being in a community selected to receive new lines funded by MCC?
- What are the impacts of being in a community selected to receive low-cost connections *and* new lines, versus only new lines?
- Do the impacts vary by gender, age, income, or urbanicity?

Our impact findings are based primarily on data from baseline and follow-up surveys that covered about 8,900 households in 358 communities.

Evaluations covered in this brief

The line extensions evaluation examines impacts of being in a community selected to receive new electricity lines. MCC funds paid for 2,595 kilometers of new medium- and low-voltage distribution lines in 7 of the country's 26 regions. To estimate impacts of line extensions, we compared outcomes of households in communities that were and were not selected to get new lines funded by MCC, adjusting for any preexisting differences found in our data. About 15 percent of the line extension communities received low-cost connections. Thus, our estimated impacts of line extensions include impacts of low-cost connections in those communities.

The low-cost-connection offers evaluation examines impacts of being in a community selected to receive low-cost connections and new lines in comparison to being in a community selected to only get new lines. MCC funds made it possible to reduce connection fees by at least 80 percent in 27 randomly selected communities out of 178 getting new lines. To estimate impacts of the low-cost-connection offers, we compared outcomes of households in the randomly selected treatment communities with those in the control communities, adjusting for preexisting differences.

IMPACTS ON CONNECTION RATES

A key outcome of interest was connection rates, and there were fewer connections than expected. In the economic rate-of-return analysis prepared

before the implementation of the energy project, MCC assumed that 35,000 new connections would be installed within a year following the construction of the lines. We estimated that there were 10,794 connections to MCC lines—about 31 percent of

Locations of the intervention and comparison communities in Tanzania by region

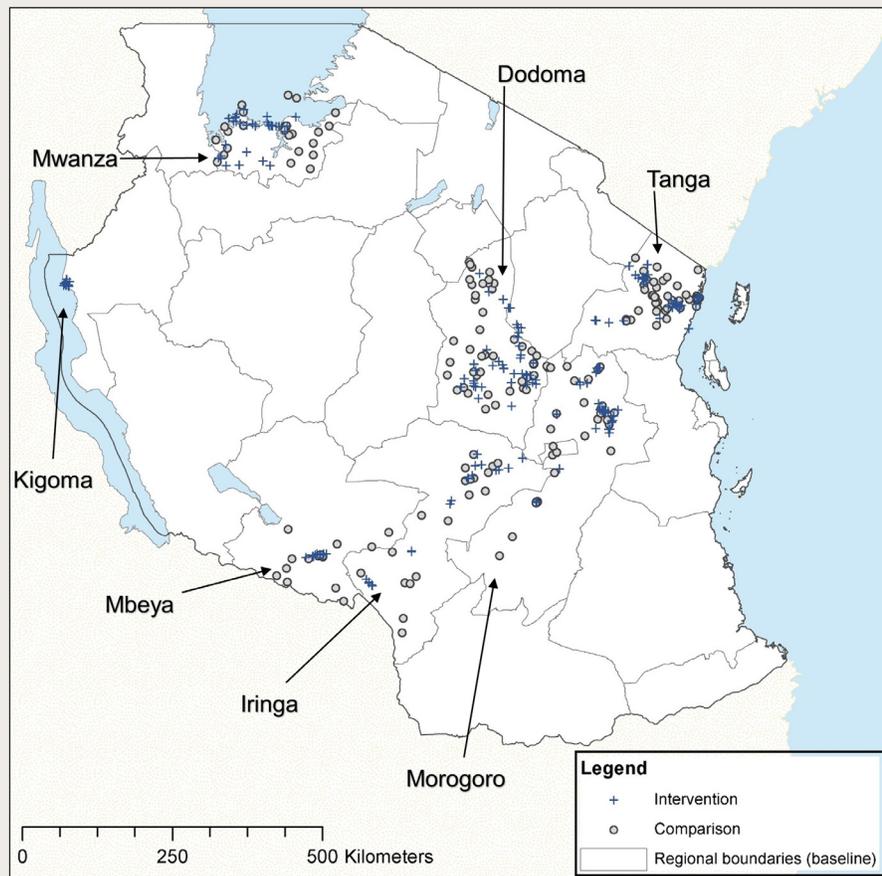


Figure 1

KEY FINDINGS

- The line extensions led to a large number of new connections, but it was less than one-third of the 35,000 connections assumed at the outset.
- The low-cost-connection offers also increased connection rates, but even if all communities received low-cost-connection offers, the number of connections originally assumed would still not have been achieved.
- The line extensions had no clear impacts on the overall amount of energy used by households, the number of hours children studied at night, whether the household operated any income-generating activity (IGA), non-electricity consumption, and in- or out-migration. However, line extensions increased consumption of grid electricity, ownership of electric appliances, time spent watching television, operation of an IGA that used grid electricity, and perceived household safety.
- The low-cost-connection offers increased electricity use and ownership of electric appliances, worsened health outcomes, and had no clear impacts on the likelihood of operating an IGA, or on non-electricity consumption; however, the offers reduced poverty as measured by per capita consumption.
- Being actually connected to the grid increased children's hours of studying at night, but it increased TV watching much more; being connected also increased income, increased the likelihood of operating an electrified IGA, and reduced poverty.

the original assumption—two to three years after the lines were constructed (Figure 2).

The line extensions increased connection rates from 11 percent to 21 percent, and the low-cost-connection offers increased connection rates from 18 percent to 31 percent (Figure 3). The fact that the estimated impact of the low-cost-connection offers was similar in magnitude to the estimated

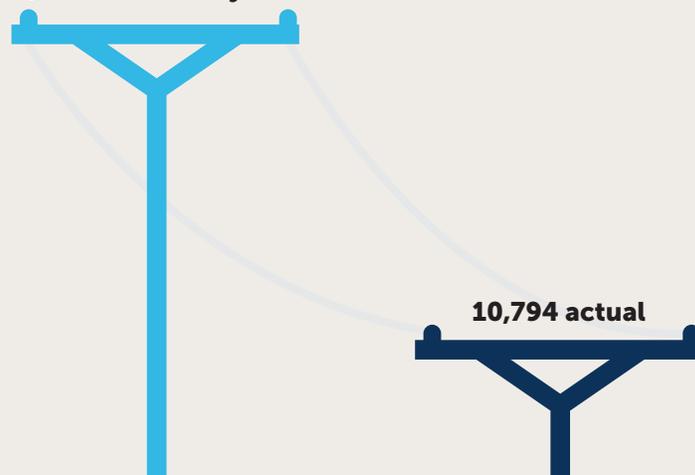
impact of the line extensions helps highlight the importance of connection costs as a barrier to the use of grid electricity in the study communities.

IMPACTS ON ENERGY USE

Even though the line extensions boosted connection rates, they had no clear impact on the overall amount of energy used by households.

Connections to MCC lines, assumed versus actual

35,000 assumed by MCC



Source: Tanzania energy sector follow-up household surveys.

Notes: Assumed connections are those MCC assumed would be achieved from the line extensions when the Tanzania energy sector project was designed. Actual connections are those estimated by Mathematica based on the follow-up data after the project was completed.

Figure 2

This seemingly puzzling result is at least partly explained by the substitution of grid electricity for electricity from nongrid sources such as generators and batteries. This substitution may have allowed households to use energy more efficiently. This is possible because generators often produce far more electricity than needed to run the appliances, tools, and light bulbs households typically use. The low-cost-connection offers, on the other hand, clearly increased the amount of electricity consumed—by about 33 percent (Table 1).

Neither the line extensions nor the low-cost-connection offers had any clear impact on liquid fuel use, which is not surprising because liquid fuel such as kerosene is already being replaced by dry cell batteries in nonelectrified households in most African countries (Peters and Sievert 2016). The line extensions and the low-cost-connection offers had positive impacts on important intermediate outcomes related directly to electricity, such as using more electric tools and appliances and spending less on recharging households' mobile phones.

IMPACTS ON TIME USE, EDUCATION, AND BUSINESS ACTIVITY

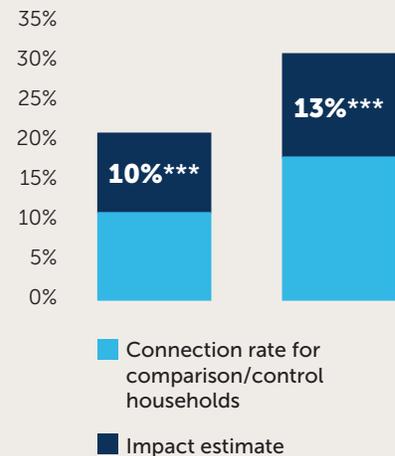
The line extensions and the low-cost-connection offers increased the amount of time that both adults and children spent watching television (Table 1). The line extensions increased the time children spent watching television by about 7 minutes per day (0.12 hours). Children in low-cost-connection offer communities watched about 11 minutes per day more television than children in non-low-cost-connection offer communities (0.18 hours). However, neither the line extensions nor the low-cost-connection offers clearly increased the time that children spent on studying at night.

The line extensions also increased the time both men and women spent collecting water and fuel. It's unclear why this result was observed, but it is possible that non-connected households experienced some negative spillover impacts from living in an electrified community. For instance, if being connected boosts household income, connected houses may develop a greater demand for water and non-electric fuel, making it more difficult for non-connected households to get those resources. People in the non-connected households may therefore end up needing to travel farther to get water and fuel.



Household electricity use

Impacts of line extensions and low-cost-connection offers on connection rates



Source: Tanzania energy sector baseline and follow-up household surveys.

Notes: The line extensions analysis sample includes 8,897 households, with 4,467 in the intervention group and 4,430 in the comparison group.

The low-cost-connection offers analysis sample includes 4,467 households, with 632 in the treatment group and 3,835 in the control group.

*** Impact estimates are significantly different from zero at the 0.01 level using a two-tailed test.

Figure 3

The line extensions increased the likelihood that households had a child attending a school with electricity. Data from our community survey also showed that 53 percent of communities that benefitted from the line extensions had an electrified school, compared with 35 percent of comparison communities. In contrast, the low-cost-connection offers, designed to help lower-income households and businesses, had no clear impact on enrollment in an electrified school, suggesting that relatively few schools needed the low-cost-connection offers in order to connect.

The line extensions and the low-cost-connection offers had limited impacts on business activities. The line extensions increased the percentage of households operating an income-generating activity (IGA) that used grid electricity from 7 to 9 percent. But neither the line extensions nor the low-cost-connection offers had clear impacts on the proportion of households operating an IGA or the proportion having a household member with a paid job.

Table 1. Impacts of line extensions and low-cost–connection offers on selected outcomes

Follow-up outcome	Line extensions		Low-cost–connection offers	
	Comparison mean	Impact	Control mean	Impact
Energy use				
Monthly amount of electricity used by the household from any source (kWh)	18.11	2.59	20.32	6.61**
Monthly amount of liquid fuel (kerosene, diesel/gas, liquefied petroleum gas) used by household (liter)	5.24	2.07	6.61	4.55
Monthly amount of grid electricity used by household (kWh)	9.00	8.00***	15.22	9.56***
Monthly amount of nongrid electricity used by household (kWh)	9.16	-5.28***	5.24	-2.74**
Number of electric tools/appliances owned by the household	3.61	0.51***	3.99	0.72***
Monthly household cost for mobile phone recharge (TZS)	2,518	-558	2,040	-540***
Time use, education, and business activity				
Average hours per night children (ages 5 to 14) spend studying	0.40	-0.02	0.35	0.02
Proportion of children (ages 5 to 14) in household attending an electrified school	0.18	0.06**	0.22	0.04
Time spent watching television (hours per day)				
Children (ages 5 to 14)	0.27	0.12***	0.36	0.18***
Men	0.36	0.09**	0.44	0.14*
Women	0.26	0.07**	0.32	0.10***
Time spent collecting fuel and water (hours per day)				
Children (ages 5 to 14)	0.83	0.01	0.83	0.12
Men	0.45	0.11**	0.54	0.11
Women	1.30	0.14**	1.42	-0.09
Household operates any IGA	0.63	0.01	0.63	-0.02
Household operates any IGA that uses grid electricity	0.07	0.02***	0.08	0.02
Household has at least one member who is a paid employee	0.18	0.00	0.17	0.02
Health and safety				
Proportion of youth (ages 15 to 24) with health problems in the last seven days	0.26	-0.02	0.24	0.07**
Proportion of children (ages 5 to 14) with health problems in the last seven days	0.29	0.00	0.28	0.07***
Economic well-being				
Annual household non-electricity consumption (thousands of TZS)	3,401	-105	3,200	435
Annual household income (thousands of TZS)	2,848	-188	2,801	4203
Household consumes less than \$1 per day per person	0.76	-0.02	0.75	-0.06***

Source: Tanzania energy sector baseline and follow-up household surveys.

Notes: The outcomes in bold are the primary outcomes in their respective domains. Impacts on other (secondary) outcomes should be interpreted with more caution. The sample for the line extensions analysis consists of 8,897 households, with 4,467 in the intervention group and 4,430 in the comparison group. The sample for the low-cost–connection offers analysis consists of 4,467 households, with 632 in the treatment group and 3,835 in the control group. Survey item nonresponse may have resulted in smaller sample sizes for certain outcomes. Appendix E in Chaplin et al. (2017) contains sample sizes for each outcome.

kWh = kilowatt hour; TZS = Tanzanian shilling; IGA = income-generating activity.

*/**/** Impact estimate is significantly different from zero at the 0.10/0.05/0.01 levels using a two-tailed test.



Hospital electricity use

IMPACTS ON HEALTH AND SAFETY

The line extensions had no clear impacts on health outcomes, but the low-cost-connection offers appear to have increased health problems related to respiration and vision among children by about 7 percentage points (Table 1). This may be because of the positive impacts on TV watching which caused children to stay inside the home longer. Because we did not find any reduction in kerosene use, which implies no reduction in indoor air pollution in the home, more time spent at home could result in increased respiratory problems.

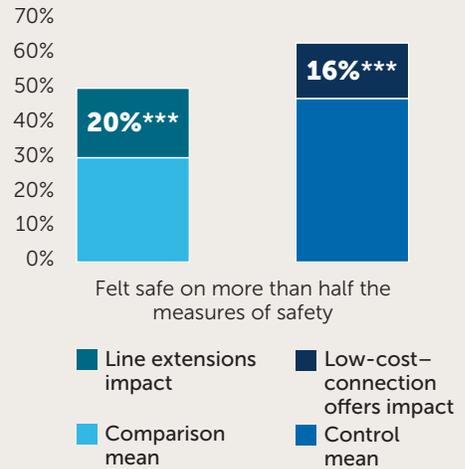
Perceived safety at night was noticeably improved by the line extensions and the low-cost-connection offers (Figure 4). To measure this, we included four questions on safety at night in the household survey. The results presented here focus on the proportion of households that responded positively to at least three of these four questions. The line extensions increased perceived safety under this definition by 20 percentage points from a comparison group mean of around 30 percent. The low-cost-connection offers also had a positive impact—increasing perceived safety by 16 percentage points from the control mean of 47 percent. The relatively large impacts on perceptions of safety may have occurred in part because even if a household is not connected, it can still benefit from the increased light at night produced from connected households in the area.

IMPACTS ON ECONOMIC WELL-BEING

Neither the line extensions nor the low-cost-connection offers had clear impacts on households' annual non-electric consumption or annual income (Table 1). However, the low-cost-connection offers lowered the proportion of households with per capita consumption of less than \$1 per day by 6 percentage points, while line extensions had no clear impact on this outcome. This finding helps highlight the potential importance of low-cost connections for poor households.

Our community-level data also suggest some economic benefit of the line extensions—in particular, it appears that they increased the price of residential land, as reported by the community survey respondents, by about 34 percent. Given that the community survey did not focus on land with direct access to electricity, this 34-percent increase likely underestimates the effect of the

Impacts of line extensions and low-cost-connection offers on perceived safety at night



Source: Tanzania energy sector baseline and follow-up household surveys.

Notes: The measures of perceived safety are based on four items in the follow-up household survey covering whether (1) communal lights around households and businesses are sufficient to help people walk at night, (2) the respondent feels safe walking in the community at night, (3) lights in the community provide some protection against crime, and (4) the lights provide protection against wild animals.

The line extensions analysis sample consists of 8,897 households, with 4,467 in the intervention group and 4,430 in the comparison group. The low-cost-connection offers analysis sample consists of 4,467 households, with 632 in the treatment group and 3,835 in the control group. The connection analysis sample consists of 8,897 households, with 1,189 in the connected group and 7,629 in the non-connected group.

*** Impact estimate is significantly different from zero at the 0.01 levels using a two-tailed test.

Figure 4

line extensions on the value of property with direct access to the new lines.

SUBGROUP RESULTS: IMPACTS BY GENDER, AGE, INCOME, AND URBANICITY

The line extensions had larger impacts on connection rates for households with a head who was age 25 or older versus households with a younger head. They also appeared to reduce hours of studying more in urban areas than in rural areas, but they improved health outcomes more in urban than in rural areas. Finally, the line extensions had a somewhat bigger impact on connection rates in higher-income

households than in lower-income households. We found no clear evidence of differences in impacts of the low-cost-connection offers by subgroup.

IMPACTS OF ACTUALLY CONNECTING

The results above cover impacts of being in a community that got new lines or in one that got low-cost-connection offers. Most households in those communities did not get connected during the time frame of our study. It is likely that the benefits of being in one of these communities are larger for those who actually connected than for those who did not. Hence, to help estimate what might happen if connection rates were substantially higher, we conducted an exploratory analysis of the effects of actual connections to the national grid on household outcomes, using a difference-in-differences approach with a matched comparison group design. In this analysis we compared outcomes for households that actually connected with outcomes of similar households that did not connect. The connected households included those in communities that received new lines funded by MCC as well as households in communities that received lines funded by other sources. As such, this exploratory analysis does not assess the impacts of MCC's investments in Tanzania, but could help us understand the potential benefits of future projects that succeed in achieving high connection rates.



Electric maize mill

As expected, actual connection to the grid greatly increased households' use of electricity, with connected households using about 82.7 kilowatt hours (kWh) per month of electricity from any source on average—nearly six times higher than in similar non-connected households in the study sample. Being connected to the grid also increased the time that children spent on studying at night—by about 12 minutes per day (0.20 hours)—compared with a 73-minute increase in their TV watching, and substantially increased the percentage of households operating an electrified IGA—from 9 percent to 26 percent. Being connected did not have clear impacts on household health outcomes. However, it did increase the proportion of households getting information about family planning and HIV by around 10 percentage points each.

Actual connection to the grid had a positive impact on connected households' economic well-being. It increased annual household non-electric consumption by 27 percent and annual household income by 49 percent. The positive impact on available resources was evident: Actually connecting reduced the proportion of households with per capita consumption below \$1 per day by 16 percentage points relative to non-connected households. (Figure 5).

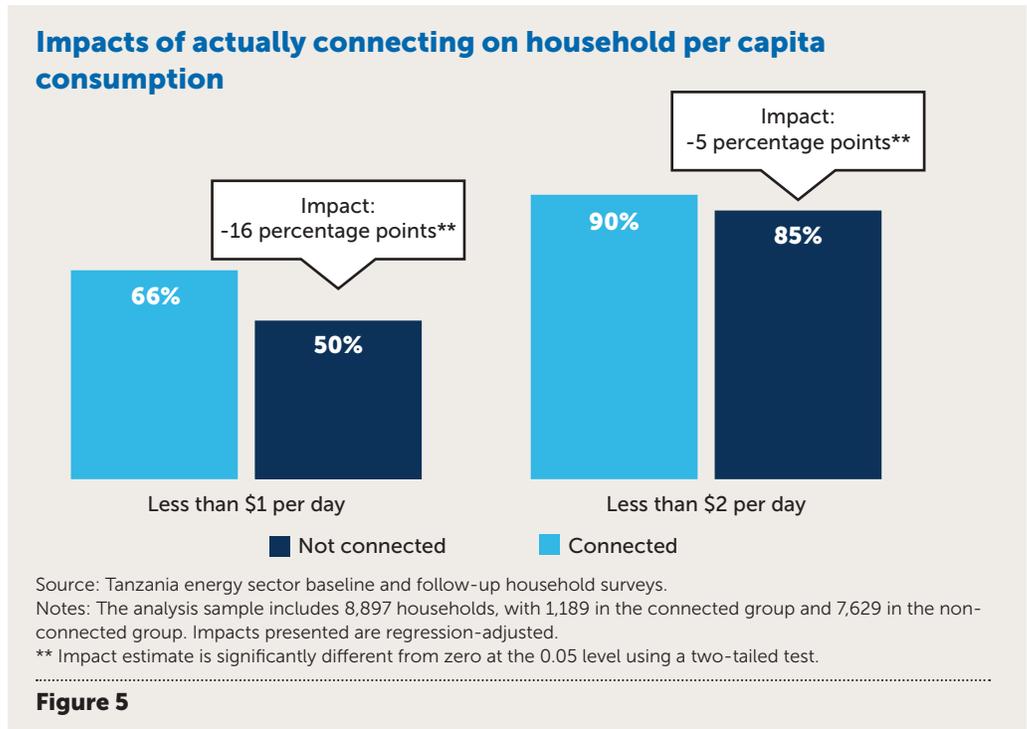


Figure 5

The impacts of actually connecting on operating an IGA were larger for households with a head below the age of 25 than for those with an older head and for households in the lowest income quartile at baseline compared to other households. Impacts on the amount of electricity consumed were larger in urban areas than in rural areas. We found no other clear evidence of differences in impacts by gender, age of the household head, urban status, or income quartile.

DISCUSSION

Our findings from the line extensions and the low-cost-connection offers evaluations, as well as the exploratory analysis of impacts of actual connections to the grid, suggest that the potential benefits of increasing access and connection to grid electricity in Tanzania are considerable and encompass a variety of economic and non-economic outcomes. However, low connection rates resulted in fewer benefits than expected from the line extensions and low-cost-connection offers.

We found no clear evidence of direct impacts of the line extensions or the low-cost-connection offers on income. However, we did find that these components of the energy sector project increased connection rates and that the low-cost-connection offers reduced poverty (measured as per capita consumption of less than \$1 per day). At the same time, we estimated larger impacts on household income and poverty for households that actually connected to the grid, compared with impacts for all households in the communities that got line extensions or for those in the communities that got low-cost-connection offers; being actually connected to the grid increased household income by about 50 percent while reducing poverty by 16 percentage points. The line extensions may have similar impacts if connection rates rise in the future. Furthermore, we found evidence that the line extensions and low-cost-connection offers improved perceptions of household safety.

However, sustainable, cost-effective expansion of access to the grid may face three serious challenges. First, compared with the annual benefits, bringing large numbers of households online may involve substantial costs related to building lines, improving capacity, and connecting households. The results of our low-cost-connection offers evaluation suggest

that reducing connection costs would increase connection rates and thus might reduce the cost of building new lines per connected household. A second challenge at the household level relates to education: although positive impacts on television watching may have some benefits, focused efforts may be needed to ensure the extra television viewing does not offset the benefits of extra studying. Third, in the area of health, greater efforts may be needed to ensure that households reduce the use of polluting fuels such as kerosene and solid fuels.

All of these issues may be worth considering when implementing future initiatives in Tanzania and when implementing projects now under way in other African countries as part of the U.S. government's *Power Africa* initiative. These issues may also come into play in related efforts supported by MCC, the U.S. Agency for International Development (USAID), World Bank, and numerous other development partners.

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