MATHEMATICA Policy Research

REPORT

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

February 24, 2017

Duncan Chaplin, Arif Mamun, Ali Protik, John Schurrer, Divya Vohra, Kristine Bos, Hannah Burak, Laura Meyer, Anca Dumitrescu, Christopher Ksoll, and Thomas Cook

Submitted to:
Millennium Challenge Corporation
1099 14th Street, NW
Suite 700
Washington, DC 20005
Project Officers: Jennifer Heintz and Shreena Patel
Contract Number: MCC-10-0114-CON-20-TO05

Submitted by:
Mathematica Policy Research
1100 1st Street, NE
12th Floor
Washington, DC 20002-4221
Telephone: (202) 484-9220
Facsimile: (202) 863-1763
Project Directors: Arif Mamun and Duncan Chaplin
Reference Number: 06919.431

This page has been left blank for double-sided copying.

ACKNOWLEDGMENTS

This report is the culmination of an 8-year project and would not have been possible without the dedicated efforts of staff at the Millennium Challenge Corporation who initiated, supported, and helped to guide this research activity. Key players included Jennifer Heintz, Shreena Patel, John "Jack" Molyneaux, Jennifer Sturdy, Laura Rudert, and Anne Rothbaum Pizer. We also thank Karl Fickenscher and Mathew Kavanagh from the MCC's Resident Country Mission in Tanzania, as well as Himesh Dhungel and Kate Iovanna from the MCC energy sector team.

Host nationals from the Millennium Challenge Account-Tanzania (MCA-T) and the Tanzanian Electric Supply Company (TANESCO) played major roles participating in, cooperating with, and supporting our efforts. At MCA-T this included Bernard Mchomvu, Issac Chanji, Chedaiwe Luhindi, Peter Kigadye, Athanas Alois, Ahmed Rashid, Paschal Assey, Joseph Hayuni, Salum Ramadhani, Florence Gwang'ombe, Reginald Ndindagi, William Christian, and Deborah Sungusia. We also appreciated the participation and cooperation of TANESCO staff.

Two firms collected the bulk of the data analyzed in this report. This report would not have been possible without the resourceful data collection implemented by staff at NRECA who collected the baseline data. We especially thank James Walsh, ATM Selim, Hussain Samad, Sylvester Ngallaba, and Saidi Nyambaya. We also sincerely appreciate the hard work of their team of interviewers, as well as the community leaders, households and businesses that participated in the surveys. At follow-up, EDI did an exemplary job finding our baseline sample, enhancing our survey instrument, and producing a high-quality dataset. Our primary contact was Amy Kahn. She was joined by a team with great depth including Respichius D. Mitti, Deo Medardi, Bhoke Munanka, Abraham Ngowi, Mark Johnson, and Matthew Wiseman. Joachim de Weerdt co-founded EDI and helped us make contact with his colleagues.

We also thankfully acknowledge support from the following entities and individuals. Camco Clean Energy took the lead on overseeing implementation of the Financing Scheme initiative. Staff from Camco, including Jeff Felten, Regina Fumbuka, Baldwin Msowoya, Rose Komba, and Cyril Batalia, helped execute the communication campaign to inform community members about the low-cost connections offered under the financing scheme initiative. Camco staff, including Andrew Mnzava, also provided the photos used in our report. DHInfrastructure, a firm with expertise in the energy sector, provided valuable input. Specifically, Denzel Hankinson, Josh Finn, Lauren Pierce, and Brendan Larkin-Connolly of DHInfrastructure supported us at various stages of the evaluation. Last, but not least, Leonard Sibomana, our consultant in Tanzania, acted as our eyes and ears on the ground throughout this project.

This report also benefited greatly from the contributions of our colleagues at Mathematica. Phil Gleason provided valuable feedback on a draft of this report. We also benefited from discussions with Ken Fortson, Steve Glazerman, Lesley Hildebrand, Frank Potter, Candace Miller, Nancy Murray, and Peter Schochet. We would like to thank Elizabeth Kelley, Ebo Dawson-Andoh, Ji-Hyeun Kwon-Min, and Miles Watkins for excellent research assistance; Xiaofan Sun, Yuhong Zheng, and Cathy Lu for programming support; Jennifer de Vallance and Brigitte Tran for help with production; Carol Soble and Amanda Bernhardt for help with editing; Kimberly Ruffin, Jessica Hegedus, and Colleen Fitts for help with formatting; and Samira Siddique, Ryan Collins, Lindsay Eckhaus, and Janine O'Donnell for help with project management. Last, but not least, Jeffrey Smith from the University of Michigan Economics Department provided very insightful and comprehensive comments throughout this report.

This page has been left blank for double-sided copying.

CONTENTS

TABLES

FIGURES

This page has been left blank for double-sided copying.

LIST OF ACRONYMS AND TERMS

ARI	Acute respiratory infections
Camco	Camco Advisory Services
CSA	Central Statistics Agency, Ethiopia
CO2	Carbon dioxide
DARESCO	Dar es Salaam and District Electric Supply Company Ltd
DID	Difference-in-differences
DWH	Durbin-Wu-Hausman
EDI	Economic Development Initiatives Limited
ERR	Economic rate of return
ESMAP	Energy Sector Management Assistance Program
FS	Financing scheme (the customer-connection financing scheme initiative)
g	Gram
GDP	Gross domestic product
GPS	Global positioning system
HBS	Household Budget Survey
ICF	ICF International
IEA	International Energy Agency
IGA	Income-generating activity
IQR	Inter-quartile range
IV	Instrumental variable
kg	Kilogram
Kijiji	village (plural vijiji)
Kitongoji	subvillage (plural vitongoji)
km	Kilometer
kW	Kilowatt
kWh	Kilowatt hour
Lao PDR	Lao People's Democratic Republic
LPG	Liquefied petroleum gas
Luku	Electric meters that allow customers to prepay for electricity in Tanzania
MCA-T	Millennium Challenge Account—Tanzania
MCC	Millennium Challenge Corporation

MJ	Megajoules
MoF	Ministry of Finance
Mtaa	Urban area (plural mitaa)
MW	Megawatt
NBS	National Bureau of Statistics, Tanzania
NGO	Nongovernment organization
NRECA	NRECA International
PM	Particulate matter
$PM_{2.5}$	Particulate matter with a diameter of 2.5 micrometer or less
PSM	Propensity score matching
PSU	Primary sampling unit
RCT	Randomized controlled trial
RD	Regression discontinuity
REA	Rural Energy Agency
T&D	Transmission and distribution systems rehabilitation and extension
TANESCO	Tanzania Electric Supply Company
TZS	Tanzanian shilling [1 USD = 1,575 TZS in 2011; 1 $ = 2,126 TZS in 2015]
UBOS	Uganda Bureau of Statistics
USAID	U. S. Agency for International Development
$	U.S. Dollar
WHO	World Health Organization

EXECUTIVE SUMMARY

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).

MCC energy sector project

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).

Evaluations covered by this report

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 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 pre-existing differences found in our data. About 15 percent of the line extension communities received low-cost connections. Thus, our estimated impacts of line extensions includes 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 pre-existing differences.

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 electricity 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 final evaluation report describes impacts of these two components of the energy sector project on a variety of outcomes for households and businesses residing in the communities where these interventions were implemented. To estimate impacts of line extensions, we used a difference-in-differences (DID) approach, comparing outcomes of households in communities that were and were not selected to get new lines funded by MCC. To estimate impacts of the low-cost-connection offers, we used a group randomized controlled trial approach, comparing outcomes of households in communities 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 previous 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 assess the degree to which these components of the energy-sector project have succeeded in achieving the goals of MCC and the Tanzanian government.

Research questions

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.

Impact findings

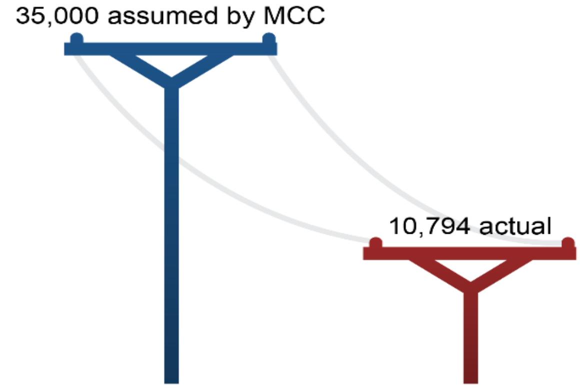
Key findings:

- The line extensions led to a large number of new connections, but it was less than a 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 have not been achieved.
- The line extensions had no clear impacts on the overall amount of energy used by households, hours children studied at night, whether the household operated any income-generating activity (IGA), nonelectricity consumption, and in- or out-migration. However, line extensions increased consumption of grid electricity, ownership of electric appliances, time spent watching television, operating 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 nonelectricity 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 perceived safety, likelihood of operating an electrified IGA, and income and reduced poverty.

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 the original assumption—two to three years after the lines were constructed.

Figure ES.1. Connections to MCC lines, assumed versus actual

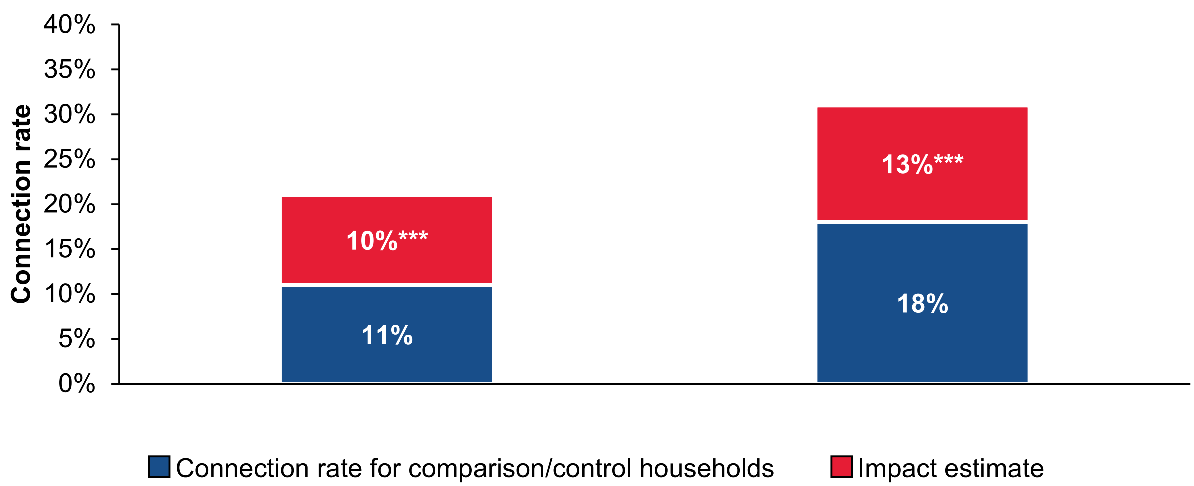


Source: Tanzania energy sector follow-up household surveys.

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.

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 ES.2). 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.

Figure ES.2. 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.

Energy use

Even though the line extensions boosted connection rates, they had no clear impact on the overall amount of energy used by households. 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 of grid electricity for nongrid electricity 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 ES.1).

Neither the line extensions nor the low-cost-connection offers had any clear impact on liquid fuel use, which is not surprising given 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.

Table ES.1. Impacts of line extensions and low-cost-connection offers for selected outcomes

	Line extensions		Low-cost connection offers	
Follow-up outcome	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
Fraction 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

Table ES.1. *(continued)*

	Line extensions		Low-cost connection offers	
Follow-up outcome	**Comparison mean**	**Impact**	**Control mean**	**Impact**
Health and safety				
Fraction of youth (ages 15 to 24) with health problems in the last seven days	0.26	-0.02	0.24	0.07**
Fraction 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	4,203
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 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.

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 ES.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.

Household electricity use

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 nonconnected 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 nonconnected households to get those resources. The nonconnected households may therefore end up needing to travel farther to get water and fuel.

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 fraction of households operating an IGA or the fraction having a household member with a paid job.

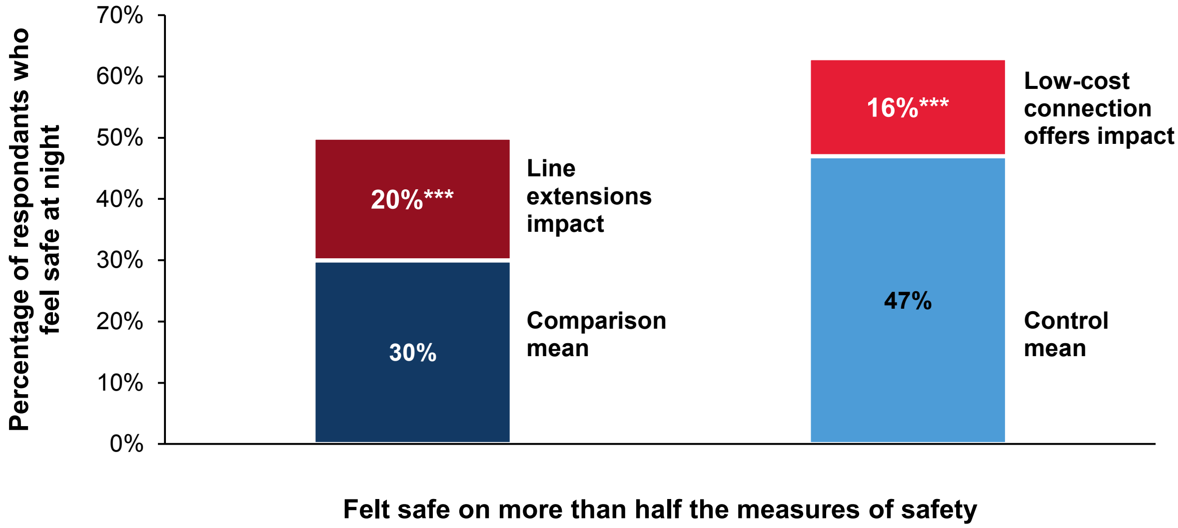
Health and safety

The line extensions had no clear impacts on health outcomes, but the low-cost-connection offers appears to have increased health problems related to respiration and vision among children by about 6 or 7 percentage points (Table ES.1). This may be related to the positive impacts on TV watching leading children to stay inside the home longer. Because we did not find any reduction in kerosene use, which likely implies no reduction in indoor air pollution in the home, more time spent at home could result in increased respiratory problems.

Hospital electricity use

Perceived safety at night was noticeably improved by the line extensions and the low-cost-connection offers (Figure ES.3). To measure this, we included four questions on safety at night in the household survey. The results presented here focus on the fraction of households that responded positively to at least three of these four questions. The line extensions increased perceived safety on more than half the questions 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 by connected households in the area.

Figure ES.3. 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 nonconnected group.

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

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 ES.1). However, the low-cost-connection offers lowered the fraction of households with 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 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 25 years or older versus households with a younger head. It also appeared to reduce hours of studying more in urban areas than in rural areas, but it 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

Most households and businesses in the communities that got the new lines and low-cost connection offers 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 (DID) 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 researchers simulate the potential benefits of future projects that succeed in achieving high connection rates.

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 that in similar nonconnected 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 fraction 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: households saw a 16 percentage point reduction in their per capita, $1-a-day poverty measure (or 24 percent relative to the poverty rate among nonconnected households).

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 head, urban status, or income quartile.

Discussion

Electric maize mill

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 spread across a variety of economic and non-economic outcomes. However, low connection rates in the communities selected for line extensions and low-cost-connection offers over the limited follow-up period produced lower than projected benefits.

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 of being actually connected than of the line extensions or of the 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 perceived household safety.

However, expanding access to the grid cost-effectively and sustainably 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: while positive impacts on television watching may have some benefits, focused efforts may be needed to ensure that these increases in watching television do not offset any benefits of increased hours of 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.

This page has been left blank for double-sided copying.

CHAPTER I

INTRODUCTION

This page has been left blank for double-sided copying.

Few households in Tanzania are connected to the national electric grid, in large part because of a lack of resources. The country's gross domestic product (GDP) per person was only $955 in 2014 (World Bank 2016), and about one-third of the mainland population and almost half of the population of Zanzibar lived in poverty (MoF 2009; Zanzibar MoF 2009). Only about 18 percent of households in mainland Tanzania were connected to the national electric grid in 2011–2012, and the rate was under 4 percent in rural areas (NBS 2014). Even those households with a connection to the grid were often subject to power surges and interruptions in service. Further, the speed of rural electrification in Tanzania has been slow because of the high cost of extending the national grid throughout the country, and it may take decades before the grid reaches the majority of Tanzanians (Ondraczek 2013). Though not sufficient on its own, improved access to reliable, high quality electricity can be a key driver of economic growth and household well-being (Barnes 2014; World Bank 2008a). Recognizing the importance of access to electricity for economic development, the Tanzanian government set out a National Electrification Program Prospectus, with plans to increase electrification rates to 50 percent by 2020 and 75 percent by 2035 (IED 2014).

In an effort to promote economic growth and reduce poverty in Tanzania, the Millennium Challenge Corporation (MCC) funded an energy sector project that was implemented by the Millennium Challenge Account–Tanzania (MCA-T). The project involves five major components, the largest two of which are both parts of the distribution systems rehabilitation and extension activity, also known as the transmission and distribution (T&D) activity—one component focuses on line extensions and the other on rehabilitation of existing lines and substations. Other components of the project include a customer-connection financing scheme initiative to facilitate lower-cost electricity connections in selected areas (hereinafter, financing scheme initiative, FS initiative, or low-cost-connection offers initiative), promotion of solar power systems in the Kigoma region of mainland Tanzania (Kigoma solar), and installation of a new submarine cable connecting Zanzibar's Unguja Island to the mainland along with rehabilitation of various parts of the Zanzibar grid (the Zanzibar interconnector activity, or cable activity). Together, these activities were designed to increase the availability of reliable and high quality electricity to people in mainland Tanzania and Zanzibar.

In this final evaluation report, we focus on two components of the project—the line extension component of the T&D activity (T&D lines) and the FS initiative (the low-cost-connection offers initiative). We also present exploratory results on the effects of connecting to the national grid. Mathematica Policy Research also conducted an evaluation of the Kigoma solar activity (Vohra et al. 2017) and an evaluation of the Zanzibar cable activity (Hankinson et al. 2011; Schurrer et al. 2015). For the T&D lines and FS initiative, we estimate the impacts on a range of outcomes within 20 to 34 months following construction of the T&D lines and within 14 to 24 months after completion of the FS initiative, depending on the community. More specifically, construction and energization of the T&D lines were completed between October 2012 and December 2013, and the deadline for applying for a low-cost connection under the FS initiative fell between August 2013 and May 2014. For the T&D lines, we analyze impacts on household- and community-level outcomes. For the FS initiative as well as the exploratory analysis of the effects of being connected to the national grid, we analyze impacts on household-level outcomes. For the various analyses, we present results on outcomes in the following domains: connection rates, energy use, educational and child time use, health and safety, business activity and adult time use, economic well-being, and household mobility and composition.

A. Overview of the energy sector project

Tanzania is one of a few dozen nations awarded a compact from MCC. At about $698 million, the Tanzania compact is the largest MCC compact to date. To manage the work of the compact effectively, the Tanzanian government created MCA-T, which implemented the project activities with oversight from MCC. To address infrastructure constraints to economic growth and poverty reduction in the country, MCA-T used the MCC compact to fund projects in three sectors: roads, water, and energy. The compact allocated about $200 million to the energy sector project (MCC 2008). We provide below a brief overview of the implementation of the two major components of the energy sector project —the T&D lines and the FS initiative—that are the focus of this report.

- **T&D lines.** T&D lines is the part of the T&D activity that involved rehabilitation of existing electricity transmission and distribution infrastructure (including new transformers and switchgears for 22 substations) as well as construction of new distribution lines in Dodoma, Iringa, Kigoma, Mbeya, Morogoro, Mwanza, and Tanga—7 of the country’s 26 regions identified in 2008 as high priority for investment in electricity. A total of 2,595 kilometers of medium- and low-voltage distribution lines were built under this activity (MCA-T 2015). The $124 million invested in the T&D activity represents more than three-fifths of MCC’s total investment in the energy sector project. As noted earlier, this evaluation focuses on the lines component of that activity.
- **FS initiative.** The FS initiative was separate but closely related to the T&D activity. It was designed to address the concern that normal connection fees present a barrier to electricity access for the majority of Tanzanian residents, particularly for those in the peri-urban and rural areas where the T&D lines were built. MCA-T and the Tanzania Electric Supply Company (TANESCO), supported by MCC, partnered to create the FS and invested about $2 million to try to reduce financial barriers and logistical constraints for residents of 29 randomly selected communities, which were identified on July 12, 2012. MCA-T procured materials for 6,000 connections (single-phase D1 connections with Luku meters that allow customers to prepay for electricity), of which 5,800 were made available in the communities for regular customers on a first-come, first-served basis; the remaining 200 connections were offered to eligible public institutions in the selected communities. Given the limited availability of a number of connection materials, we determined a quota for each community proportional to the number of households in the community; in the end only two communities reached their quota.

The FS initiative lowered the connection fee by over 80 percent, to 30,000 Tanzanian shilling (TZS). It was 320,960 TZS in urban areas and 177,000 TZS in rural areas.[1] Customers could use the FS low-cost-connection offer to connect to MCC-funded lines as well as to the existing non–MCC-funded lines. Customers still had to pay an application fee of between 4,500 and 5,900 TZS and had to pay for wiring their homes, which can easily cost as much as or more than the standard connection fee. The low-cost connection offer was available to community members only after the new lines were energized; community members then had between 60 to 90 days to take advantage of the offer. A communications campaign carried out by Camco Clean Energy (Camco) as part of the FS initiative informed households about the low-cost connection offers. Implementation of the FS initiative occurred from February 2013 to June 2014, with 1,814 connections made under the FS initiative (about 31 percent of the available connections).

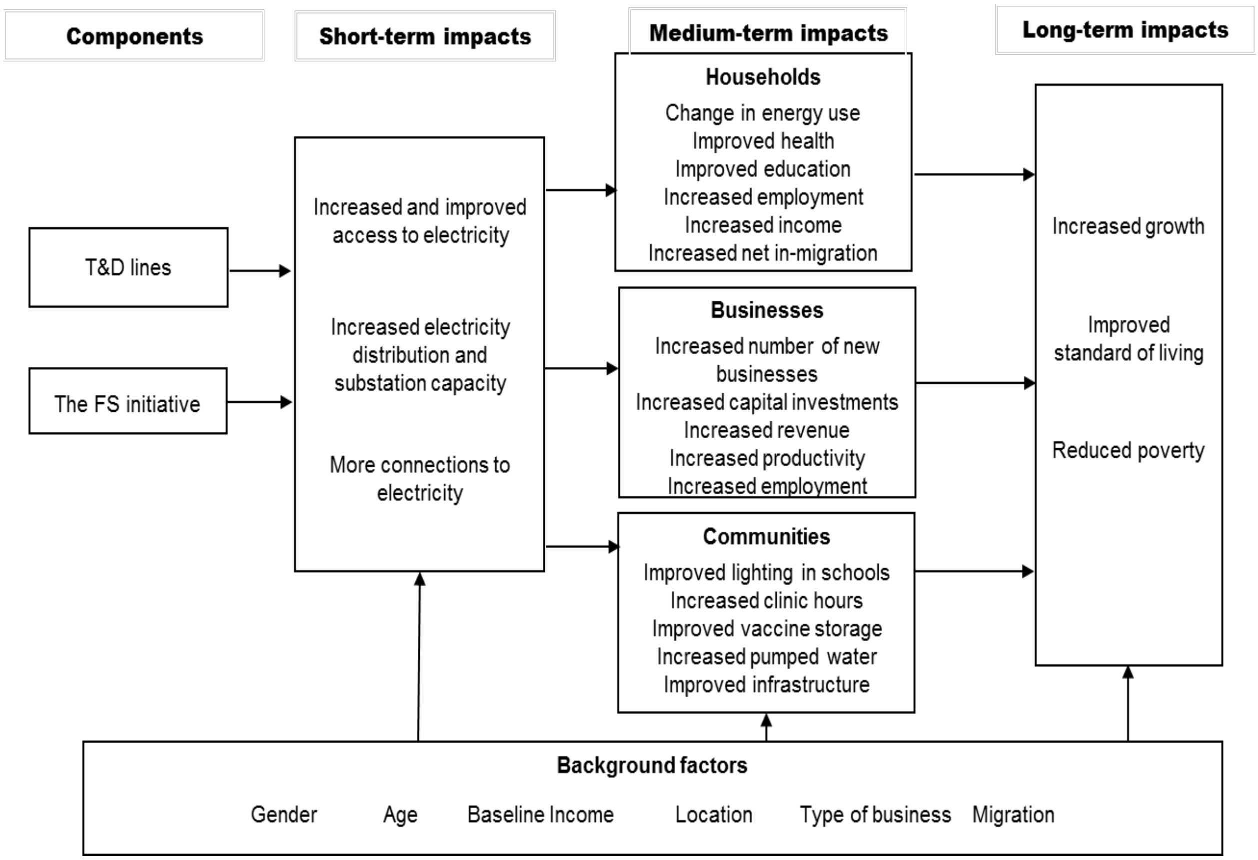
Through the above investments in the energy sector, MCC intended to help Tanzania take fuller advantage of its economic growth potential and ultimately improve the well-being of its people. Mathematica's evaluation of the energy sector project helps assess the degree to which the T&D lines and FS initiative have succeeded in achieving their goals. In the remainder of this chapter, we provide a conceptual framework for the overall energy sector project. We conclude the chapter with a roadmap of the rest of the report.

B. Project logic and conceptual framework for the T&D lines and FS initiative

MCC and MCA-T have developed a set of logic models for each activity under the energy sector project (MCA-T 2012). Mathematica consolidated the logic models into a conceptual framework (Figure I.1) that guides our approach to the evaluation of the project activities. The boxes on the far left of the figure show the two components of the energy sector project covered in this report. The box on the far right shows the ultimate objectives of the activities—increased economic growth, improved standard of living, and poverty reduction. The project components are designed to achieve these objectives through their effects on access to electricity, which will be realized in the short term, and through subsequent effects on households, businesses, and communities, which will be realized in the medium and longer terms.

[1] The initial plan was to lower the connection fee to 80,000 TZS compared to the standard connection fee of 461,000 TZS (in both urban and rural areas). However, in January 2013, before community outreach was conducted to inform potential customers about the low-cost connection offer, TANESCO lowered the standard connection costs to 320,960 TZS in urban areas and 177,000 TZS in rural areas. To keep the FS initiative attractive to the customers, in consultation with MCC and TANESCO, MCA-T lowered the discounted connection fee to 30,000 TZS, which is about the same amount customers in rural areas would pay as value added tax on their standard connection fee. Customers also paid an application fee of 5,900 TZS. Thus, for each low-cost connection, customers paid a total of 35,900 TZS.

Figure I.1. Conceptual framework for the Tanzania T&D lines and FS initiative



In the short-term, the T&D lines and the FS initiative can affect access to electricity in several ways, as shown in the box in the second column of the conceptual framework. First, the successful implementation of the T&D lines is expected to increase the reach of distribution networks and improve substation capacity. Second, by expanding the distribution network and facilitating lower-cost connections, the T&D lines and the FS initiative can increase the number of households, businesses, and community organizations (such as schools, health facilities, and water utilities) connected to the national grid, likely leading to increased use of electricity.

These improvements in access to electricity can have important medium-term impacts on households, businesses, and communities, as presented in the third column of the conceptual framework. Electricity can change the sources and amount of energy used by the household. It can also help improve households' economic opportunities by enabling household members to spend less time performing household chores during the day, consequently freeing up time to work for pay outside the home. Further, it can help households obtain valuable information on the market prices of goods and services, adverse weather conditions, and opportunities available to them via radio and television programming and mobile phone communications. Electricity can improve health outcomes if it enables households to reduce the use of certain types of fuel that are likely to cause health problems, such as kerosene, charcoal, and wood. Electricity can improve safety outcomes by providing outdoor lighting at night that may deter crime. It can improve education outcomes by enabling students to spend more time reading after dark. For all of these reasons it can increase in-migration by making the community more attractive to outsiders.

Electricity can also have important impacts for businesses and communities. In particular, it can enable businesses to use many types of machinery that cannot be operated cost-effectively without electricity. Similarly, electricity can be used in important and cost-effective ways by facilities that serve entire communities, such as schools (which can benefit from electric lights), clinics (which can stay open for longer hours, use electricity for refrigeration, and use certain types of medical equipment), and water utilities (which can use electricity for pumps and cleaning equipment). For all of these types of uses, grid electricity from the new T&D lines funded by MCC is likely to be far less expensive than electricity produced by the small generators commonly used by many businesses, schools, and health facilities that operate some distance from the existing electric grid. Finally, provision of electricity in a community may increase investments in other types of infrastructure if it improves community well-being and hence demand for such improvements.

Last, but not least, the medium-term outcomes can in turn affect longer-term outcomes. These include economic growth, the standard of living, and poverty. All of the medium-term outcomes can affect economic growth. While we cannot capture growth well in the short time frame of our study, we do look for impacts on household income. We also do not try to separate the improved standard of living outcomes shown as long-term outcomes from our medium-term outcomes but in theory the medium-term outcomes we do capture could affect longer-term outcomes such as life expectancy and completed years of education. Finally, since the initiative is focused on rural and peri-urban communities where large fractions of the population are living in poverty, we expect that impacts on income are likely to reduce poverty. We focus in particular on the fractions of households living on less than $1 or $2 per person per day.

The box at the bottom of the conceptual framework shows background factors that may affect the short-term, medium-term, and long-term outcomes of interest. It will be important to control for differences in these background factors when we conduct our impact analyses. In addition, impacts of the activities may vary across different subgroups of the population. Women and children, for example, may benefit most from electricity in the house, as they spend more time there. Our evaluation will pay particular attention to differences by gender, as that is a strategic priority for MCC and MCA-T. Additionally, low-income households may benefit least if they cannot afford the connection fee or electric appliances. Benefits to businesses may depend on their use of electrical equipment. Communities may differ in the benefits they gain from electricity, depending on the number and type of public facilities they operate. Finally, migration may matter, especially if large numbers of new households migrate into communities that become electrified. Although we will not be able to rigorously estimate benefits for migrating households, we conduct a number of related analyses to help capture impacts that might be related to migration.

C. Organization of this report

In Chapter II, we present a literature review that covers the history of electrification in Africa, relevant policies, and research on the impacts of electrification. In Chapter III, we describe the research questions and the evaluation design. In Chapter IV, we outline the sample and the data used for the analysis as well as the empirical methods used to estimate the impacts of both components. In Chapter V, we discuss the impact findings for the T&D lines, including those for the sample as a whole and for various subgroups. In Chapter VI, we present the impact findings for the FS initiative's low-cost-connection offers. We present exploratory evidence on the impacts of connection to the national grid in Chapter VII as well as an assessment of whether a nonexperimental approach to estimating impacts of the FS initiative could produce similar results compared to the randomized experimental approach we applied. We conclude in Chapter VIII with a summary of the findings and a discussion of the implications for policy and practice.

Appendices provide information and data supporting our main analyses. We present a discussion of weights in Appendix A, baseline equivalence tables in Appendix B, a detailed description of all community and household-level outcome variables in Appendix C, a description of constants or conversion factors (for example, the amount of pollution created by burning a liter of kerosene) used to create various summary measures in Appendix D, supplementary tables including results from several robustness checks in Appendix E, and discussions of additional technical issues in Appendices F, G, H, and I.

CHAPTER II

LITERATURE REVIEW

This page has been left blank for double-sided copying.

Although many developing countries have made great strides in increasing access to electricity, it is well-established that most low-income African countries lag far behind in expanding access especially in rural areas. Much of the progress in developing countries in recent years has been driven by the rapid expansion of electricity in India; in Africa, the pace of electricity growth has only barely exceeded population growth (IEA and World Bank 2015). In particular, Tanzania has one of the lowest rates of electrification in the world (World Bank 2016); only 18 percent of households in mainland Tanzania had access to electricity in 2011–2012 (NBS 2014). The challenges to improving Tanzania's electricity rates abound. Access rates are lowest in rural areas because low-density areas are more expensive to electrify. Even where lines are built, household connection rates are often low, largely because of high connection costs. In both rural and urban areas, poor households connected to the grid exhibit low usage (Louw et al. 2008; IEA 2014). In addition, although connection costs are too high for many low-income customers, usage tariffs are often particularly low; as a result, utilities' total revenues often fall well below costs. All these factors provide a disincentive for private companies and electric utilities to expand into unreached areas.

At the same time, both policy and research have undergone a dramatic shift regarding electricity access in Africa. A growing number of donors are now funding electricity projects in Africa, notably the United States–sponsored Power Africa initiative, announced in 2013. Energy is one of the 17 Sustainable Development Goals for 2030, with the goal of universal access to affordable, reliable, and modern energy services by 2030 (United Nations 2016). In addition to policy initiatives, research on electricity in developing countries has shifted in the last decade to an emphasis on estimating causal links between efforts to improve electricity access, connection rates, and impacts on factors such as energy and time use, education, health, and income.

The background information presented in this literature review is important to consider when reviewing the rest of our report. The MCC energy sector project in Tanzania was justified in part based on the assumption that a large number of households would immediately connect to the new lines. As explained elsewhere in this report that did not happen. This delay might have been predicted given evidence we cover in this chapter and suggests the need for greater caution when developing future interventions similar to the one implemented here.

This literature review provides context and evidence relevant to key components of the Tanzania energy project by covering the history, policy, and research related to expanding grid electricity access and connections in developing countries. The chapter is organized as follows. In section A, we provide context by presenting a brief history of electricity investment in Africa, a topic covered in greater detail in Bernard (2012). In section B, we review the challenges to expanding access to electricity in developing countries, a topic that is relevant to the evaluation of the T&D lines. Next, in sections C and D, we describe household barriers to connecting to electricity and the various interventions that have been implemented to reduce the cost of connecting to the grid. These sections are applicable to the FS initiative. In section E, we discuss evidence on how long it takes households to connect once electricity is available and, once connected, how long it takes for benefits of electricity to manifest in various household outcomes; these topics are relevant for the evaluation of both the T&D lines and FS initiative. In section E, we also discuss research on the impacts of connecting to electricity, with an emphasis on more rigorous studies that attempt to establish causal links. This discussion is organized in a way that roughly corresponds to the domains covered by the impact evaluation: fuel and energy use, education, health and safety, time use, economic activity and well-being, and household composition and mobility.

A. History of electricity investments in Africa

Efforts to increase electricity access in Africa, particularly in rural areas, have been ongoing for decades. During colonial times, electricity lines were installed primarily to support colonial powers' industrial projects (Cook et al. 2015). Rarely was electricity installed with the goal of improving household access. As a result, the majority of African households lacked electricity, a condition seen as a barrier to economic growth during what Bernard (2012) describes as the first of three distinct periods in the recent history of rural electrification in developing countries. In the first period, lasting from decolonization until the early 1980s, infrastructure was viewed as a key to economic growth. Electricity in particular was deemed crucial for improving conditions in rural areas and thereby slowing the rate of deforestation and the rate of migration to urban areas. Large-scale state-led energy projects, including the construction of hydroelectric dams, were popular during this period, and electricity was highly subsidized (Cook et al. 2015, Williams and Ghanadan 2006).

During the 1980s and early 1990s, the focus switched from government and donor-funded rural electrification projects to structural adjustment policies, through which the World Bank pushed for the unbundling and privatization of state-owned utilities. Donors and governments realized that large-scale investment in infrastructure had led to substantial debt burdens in developing countries, a situation compounded by the oil shocks of the 1970s. Artificially low electricity prices meant that many utilities could not cover their costs, and systems were plagued by electricity shortages, poor quality equipment, and inability to expand the grid (Williams and Ghanadan 2006). Even where rural electrification access had expanded, connection rates were low (typically between 25 and 50 percent), and few households used electricity for anything beyond lighting (Bernard 2012). Households did not change their cooking practices and thus did not reduce their reliance on wood, and there was no evident slowing of rural-to-urban migration. This second period of rural electrification described by Bernard was characterized by international donors' unwillingness to invest in electricity in particular because of the lack of success and in infrastructure in general because of government corruption and poor economic performance (Cook et al. 2015; Bernard 2012). Rather, at the behest of the World Bank and International Monetary Fund, governments in developing countries implemented structural adjustment programs that promoted market competition and reduced government control over the economy, encouraged privatization of state-run industries, and facilitated foreign private investment. In general, these reforms failed to increase private investment in the power sector in Sub-Saharan Africa (Jamasb et al. 2015).

Finally, the third period described by Bernard started in the 1990s, when electrification came to be seen as a means of poverty reduction and, specifically, as a key input to achieving the Millennium Development Goals. In contrast to the 1970s and 1980s, international development partners now focus on rural electrification through various strategies beyond grid expansion and low tariffs, including off-grid and renewable energy, subsidies, financing schemes targeting the poor, and coupling electrification with education and financial incentives designed to encourage the productive use of electricity (Bernard 2012). In addition, an increasing number of impact studies have been conducted to determine the causal effect of these programs on electricity access, connection rates, and individual and household choices. Nonetheless, rigorous evidence on the impacts of expanded electricity access remains limited, particularly in Sub-Saharan Africa.

Today, several major donors are involved in expanding access to electricity in Africa. The World Bank, a coleader of the UN's Sustainable Energy for All Initiative, has provided almost $50 billion in energy financing since 2010. MCC has funded several electricity projects, including new Power Compacts in Benin, Ghana, and Liberia. The U.S. government announced Power Africa in 2013 as a major initiative to increase access to electricity in Africa. Twelve U.S. government agencies participate in Power Africa and by 2015 they had committed approximately $9.7 billion through 2018 (Cook et al. 2015). Goals call for supporting and strengthening institutions, promoting private investment, adding 30,000 megawatts (MW) in electricity generation capacity, and increasing connections among households and businesses. Although it initially targeted only six countries—Ethiopia, Ghana, Kenya, Liberia, Nigeria, and Tanzania—Power Africa has since expanded to a total of 43 countries and provides assistance to regional organizations. It has headquarters located in Pretoria, South Africa and Washington, DC. Its field presence is led by the U.S. Agency for International Development (USAID).

In Tanzania, the electricity sector is operated by the public utility TANESCO under the regulatory authority of the Energy and Water Utilities Regulatory Authority (Miller et al. 2015). German colonialists installed Tanzania's first public electricity supply in 1908 in Dar es Salaam (TANESCO 2016). In 1931, the British colonial rulers privatized electricity production, leading to the formation of TANESCO (then the Tanganyika Electric Supply Company Ltd) and the Dar es Salaam and District Electric Supply Company Ltd (DARESCO). Tanzania installed its first dam in 1936, opened the Hale hydropower plant in 1964, and constructed two dams as part of the Great Ruaha power project between 1969 and 1981. During this same period, the government purchased all shares from TANESCO and DARESCO and the two companies merged into one organization. Although the energy sector has been open to the private sector since enactment of the national energy policy in 1992, it is still dominated by TANESCO. Grid expansion projects are funded by either the state or donors, including the World Bank, MCC, the European Union, the Norwegian Agency for Development Cooperation, and others (Kitonga 2015; REA 2014). However, this may soon change, as recent electricity sector reforms in the country have called for increased private sector investment and for TANESCO to be replaced by multiple companies that separately manage electricity generation, transmission, and distribution (Ministry of Energy and Minerals 2014; Kitonga 2015). In addition, Power Africa has already leveraged more than $20 billion in private sector commitments in Sub-Saharan Africa and is providing technical advice to Tanzania to improve the climate for private investment (Cook et al. 2015; USAID 2015b).

The movement to involve the private sector in the provision and distribution of electricity is partly attributable to Tanzania's ambitious plans to increase overall electricity generation capacity. As part of Tanzania's goal to become a middle-income country, Tanzania's Energy Supply Industry Reform Strategy and Roadmap 2014–2025 suggests that the country needs to increase its power capacity from 1,582 MW in April 2014 to at least 10,000 MW by 2025 and raise connection rates from 24 to 50 percent by 2025 and to 75 percent by 2033 (Ministry of Energy and Minerals 2014). The plan estimates the need for $11.4 billion in the first five years, about 75 percent of which would be designated for power generation. To meet these financial needs, the government expects to leverage private capital investment in addition to relying on government funds and development partners' resources. The government has made a noticeable effort to attract private investment through the Public Private Partnership Act of 2010 and the Private Partnership Regulations in 2011 and received a record $1.1 billion in foreign investments in 2012 (USAID 2015a).

The sector is also experiencing dramatic changes in the supply of electricity. Historically, hydroelectric power plants generated almost all of Tanzania's electricity. In 1990, for example, hydroelectric sources accounted for 95 percent of Tanzania's electricity (World Bank 2016). By 2000, the share had fallen slightly to 86 percent, with most of the remainder coming from oil. Today, hydroelectricity represents only 50 percent of Tanzania's total electricity production. Natural gas's share of production increased from zero in 1990 to 29 percent in 2012 while oil and renewable resources accounted for 20 and 0.5 percent, respectively, of electricity production; no coal was used in 2012 (World Bank 2016). However, the government plans to meet its energy production goals in part by tapping the country's coal reserves and increasing the use of natural gas (World Bank 2016; Makoye 2014). The plan estimates that roughly two-thirds of Tanzania's electricity production in 2025 will come from coal and natural gas and that only 19 percent will come from hydropower (Makoye 2014). Although hydropower capacity is likely to increase, recent droughts have hindered production and have led policymakers to look for alternative energy sources.

B. Challenges with expanding access

Despite increased interest in catalyzing private sector investment, the private sector—for a variety of reasons—may have little incentive to invest in Tanzania's power sector. The most commonly cited reason is the enormous expense of extending lines to remote and often sparsely populated rural areas. For example, a study in Western Kenya found that the median cost of installing a transformer was $21,820 and the median infrastructure investment per connection was $2,427 because of low connection rates (Lee et al. 2016a). Government officials and technical experts in Tanzania have listed the high supply cost per connection and shortage of connection materials as major barriers to expanding the grid (Ahlborg and Hammar 2014; Miller et al. 2015).

In addition to the cost of line extensions, utilities see little benefit in expanding to rural and poor urban areas, where take-up rates are often extremely low. Evidence from Botswana showed that only 12 percent of households in electrified villages connected to the grid (Ketlogestwe et al. 2007), and, in Ethiopia, only 39 percent of households in electrified communities connected to the grid (Bernard and Torero 2009). Even among households that connect, their usage has been lower than projected. In South Africa, average household electricity consumption was 132 kilowatt-hours (kWh) per month versus 50 kWh hours in low-income households (Louw 2008). In Tanzania and Mozambique, usage is estimated to be less than 200 kWh per capita per year (IEA 2014). In urban areas, where connection rates are higher, theft and illegal use remain a major problem given insufficient enforcement of rules and regulations (World Bank 2010). African cities are also often less dense than cities in other parts of the world, making infrastructure provision more expensive (Foster and Briceño-Garmendia 2010). All these factors increase the cost of supplying electricity.

Additional challenges persist at the institutional and supply level. Many low-income countries lack the capacity to expand electricity lines rapidly and then maintain them properly (World Bank 2010). The quality of the supplied electricity is low and characterized by frequent outages. One study reported that firms in Africa lose 5 percent of their sales because of power outages (Foster and Briceño-Garmendia 2010). Specifically, the economic cost of power outages in Tanzania was estimated to be over 4 percent of GDP in 2007, while the cost of emergency power generation was about 1 percent of GDP (Foster and Briceño-Garmendia 2010). In interviews with government officials, donors, and technical experts in Tanzania, Ahlborg and Hammar (2014) as well as Miller et al. (2015) found that an inefficient top-down structure, unrealistic planning, lack of local participation in planning, long lags between design and construction, and inadequate coordination in the process used to resettle and compensate households forced to move to make way for the new lines were major reasons for the slow pace of rural electrification in Tanzania. Furthermore, the authors indicated that donor funding poses challenges. Specifically, the lack of coordination between/among donors is a time drain for TANESCO and the Rural Energy Agency (REA), an autonomous agency that facilitates improved access to modern energy services in rural Tanzania. Further, the authors expressed concern that the low connection charges and high levels of compensation for loss of property of donor-funded projects make government-funded line extension look bad in comparison. This, in turn, makes it harder to gather community support and interest for the government-funded projects (Ahlborg and Hammar 2014). These challenges are further exacerbated by politically motivated tariffs, as discussed below, though some may be alleviated by policies of the Power Africa initiative discussed earlier.

C. Barriers to connecting

The government of Tanzania, recognizing very low connection rates in rural areas, passed the Electricity Act in 2008, a reform effort that encourages private sector investment in off-grid systems, sector restructuring, regulatory oversight, and the creation of the REA (Ahlborg and Hammar 2014). REA has noted in its annual reports that the percentage of rural villages with access to electricity has risen sharply in the last few years, from 2.5 percent in 2010 to 7 percent in 2013 and 17 percent in 2014 (REA 2013; REA 2014). However, data from other sources show more modest increases in household connection rates, estimating that 3.8 percent of rural households were connected to electricity in 2013, up just 0.9 percentage points from 2007 (NBS 2014; NBS and ICF Macro 2011; IEA 2015). In 2012, the estimated connection rate for mainland Tanzania as a whole was 18.2 percent, driven by higher connection rates in Dar es Salaam and other urban areas, at 68.1 and 34.7 percent, respectively (NBS 2014). Rural electrification rates are similarly low in other countries in Sub-Saharan Africa. For example, about 5 percent of rural households in Ethiopia were connected to electricity in 2011 compared to 85 percent of the country's urban households (CSA and ICF 2012). In Uganda, 5.3 percent of rural households and 55.4 percent of urban households had electricity in 2011 (UBOS and ICF 2012).

These aggregate numbers do not reveal what percentage of households in Tanzania with access to electricity actually connect, though it is possible to combine the above access rates and connection rates from 2013 to come up with an estimate of 54 percent in rural areas (3.8 percent connecting divided by 7 percent with access in rural areas in Tanzania). In any case, the figures cited above from Botswana and Ethiopia indicate that connection rates remain low even where electricity is available.

The literature on the barriers to connecting is fairly extensive. The main reason cited for low take-up rates is typically cost. In Africa, the typical connection cost borne by rural households is $50 to $250. In Rwanda, one study found that the median cost to connect was $200 (Bensch 2011). In Tanzania, the average total cost to connect was about $300 in 2011 for a house within 30 meters of the line (Chaplin et al. 2012). The cost increased to $870 for houses needing the installation of one additional pole and to over $1,200 for houses needing the installation of two additional poles (Golumbeanu and Barnes 2013). In addition to the connection fee, households have to take into account the cost of wiring their dwelling, which can be as expensive as if not more expensive than the basic connection fee (Chaplin et al. 2012; Miller et al. 2015). In Ethiopia, 41 percent of nonconnected households listed financial reasons as their primary reason for not connecting (Bernard and Torero 2009). In addition, households in Tanzania are deemed unsuitable for electrification if they are constructed of mud and grass. One consultant estimated that only 10 percent of the population would be able to afford to connect and meet structural requirements (Ahlborg and Hammar 2014). This may also be a problem in urban areas, where households in informal settlements are often ineligible to be connected (World Bank 2010).

Given that electricity is probably a substitute for other fuels already used by a household, the connection cost is likely to be more of a barrier than the monthly cost for electricity consumption (Chaplin et al. 2012; Golumbeanu and Barnes 2013). A study in three urban areas in Tanzania found that electricity (given large subsidies) had the lowest price per kWh in almost all study areas as compared to firewood, charcoal, kerosene, and liquid petroleum gas (Hosier and Kipondya 1993). Chaplin et al. (2012) also suggest that the potential savings that accrue to households over a period of a few years after the switch to grid electricity as a sole replacement source of energy would be sufficient to cover the fixed costs of connecting to the grid. A study in Guatemala found that electricity was only slightly more expensive than fuelwood when used for cooking and was cheaper than candles and kerosene when used for lighting (Foster et al. 2000). It was also far cheaper than dry cell batteries. Thus, given that electricity is so much cheaper than other fuel sources, it likely saves households a great deal of money, though many households may spend the savings on additional energy in the form of electricity or other sources. Some households in Tanzania reported large increases in their energy bills, particularly if they started using large appliances (Miller et al. 2015). In addition, some households did not realize that they would have to pay a monthly fee for electricity in addition to the amount of electricity they consumed, making it hard for them to plan for their expenses (Miller et al. 2015).

Even where the initial connection cost is spread over many months, households with seasonal income may find it difficult to make regular payments. In a related matter, households may not understand the billing system, or they may find that the administrative process associated with the initial connection is overly burdensome. For instance, Miller et al. (2015) found that, in Tanzania, households neither understood the connection process nor expected the lag between the decision to connect and the actual connection. A study in Benin found that households that did connect to the grid consumed less energy than expected, suggesting that they did not fully understand the billing process (Peters et al. 2009). In Ethiopia, 41 percent of households cited administrative reasons as the primary reason for not connecting to the grid (Bernard and Torero 2009). Only 17.6 percent reported that they did not connect to the grid because they had no need for electricity.

Another frequently cited explanation for low connection rates is that households are not fully aware of electricity's potential benefits or they see it as a luxury good (Cook 2011; Peters et al. 2009; Bernard 2012). Households that have not been exposed to electricity, either through their own use or through the use of neighbors or family, may not realize its many practical applications. Ranganathan (1993) cites the lack of a "demonstration effect" and suggests that a critical mass of connected households is needed to make household electricity the norm. Winther's (2007) observations in Zanzibar support her argument. She found that, over 10 to 15 years, community members learned about the benefits of electricity through either their own use or by observing their connected neighbors' use of electricity, creating a much greater demand for electricity than initially existed. Winther explained that the high demand for electricity ended up recasting it as the norm so that a house without electricity was considered "unfinished" (Winther 2007). Similarly, although Bernard and Torero (2015) found that households had a thorough understanding of the benefits of electricity before they connected to the grid, the authors also found that "each additional neighbor connected within a 30 meter radius increased a household's connection probability by about 2 percentage points." Thus, even though cost is surely an important factor, the demonstration effect may mitigate the cost barrier—whether that results in an improved understanding of benefits or competition to keep pace with one's neighbors in terms of home quality and possessions.

D. Interventions to reduce costs

Pricing of electricity is often a highly sensitive political issue. Governments and donors have implemented several strategies to reduce connection costs while increasing connection rates. Historically, the strategies for decreasing the cost of electricity consumption have focused on subsidies and low tariffs, but experience has demonstrated that most such strategies are regressive, meaning that they disproportionality benefit higher-income households (Golumbeanu and Barnes 2013; Foster and Briceño-Garmendia 2010; World Bank 2010). Where connection rates are unaffordable, electricity price subsidies help only those who are already connected. In addition, subsidies drive up costs and prevent electricity providers from extending the grid rapidly in the absence of any incentive to do so (Golumbeanu and Barnes 2013).

In the 1990s, Tanzania instituted a lifeline tariff for the purpose of providing low levels of electricity to households for a fraction of the real cost of supplying electricity. Under the tariff structure, households consuming less than 1,000 kWh per month were charged the lowest tariff rate, and households consuming less than 2,501 kWh per month were charged a slightly higher rate. For households that used more than 2,500 kWh of electricity per month, the tariff was much more closely aligned with the actual cost of supplying electricity; however, such households accounted for only a small percentage of all households—those that were wealthy enough to consume far more electricity than the average Tanzanian household (Hosier and Kipondya 1993). Hosier and Kipondya (1993) estimated that, in 1990, the price charged to households using little electricity was 15 to 20 times less than the supply cost, resulting in large operating deficits for TANESCO every year. In recent years, Tanzania has increased the tariffs in an effort to improve TANESCO's financial position; nevertheless, prices remain lower than those in other East African countries as well as below what TANESCO has requested (The Economist 2014). In an interview, one consultant reported that the current tariff in Tanzania is half of what is needed to cover the production cost of grid electricity (Ahlborg and Hammar 2014).

A high connection cost is a major barrier to connecting: research suggests that every $10 increase in the connection charge in Africa results in a 0.5 percent decrease in the connection rate (Golumbeanu and Barnes 2013). Among the various strategies for reducing the connection cost for households are the subsidization of the connection charge, the incorporation of the connection charge into the tariff to spread the cost over time, financing the charge through a bank, and the offer of credit schemes to allow repayment over time (Golumbeanu and Barnes 2013). Recently, some African countries have adopted new strategies. A few of these approaches are summarized in Table II.1.

Table II.1. Programs to reduce connection costs in Africa

Country	Program	Strategy
Senegal	Rural Electrification Priority Program	Provides the connection, internal wiring, and a fluorescent lamp to low-income households for a discounted fee, which the household then repays over 10 years at a 15 percent interest rate
Liberia, Kenya, and Uganda	Global Partnership on Output-Based Aid (the World Bank)	Utility companies provide electricity connections at a lower cost to low-income households and receive reimbursement for the discount amount only after meeting certain requirements, such as a specified number of connections
Ethiopia	Electricity Access Rural Expansion Project, Phase 2 (the World Bank)	Connects poor households at 20 percent of the typical connection cost and provides the households with two fluorescent lamps. Households pay the remainder over 5 years at no interest while the utility receives a subsidy to cover the interest and cost of the lamps.
Ghana	National Electrification Program/Self-Help Electrification Programme	Communities within 20 kilometers of a medium-tension electricity line built low-voltage distribution poles themselves, thereby reducing the utility company's cost of extending the grid

Source: Golumbeanu and Barnes 2013

Each of these programs shows promise as an effective means of increasing connection rates among low-income households. In particular, the Self-Help Electrification Programme in Ghana has earned acclaim as a huge success and explains in part why Ghana has a higher rural electrification rate (40 percent) than most other Sub-Saharan African countries (World Bank 2016).

A strategy for empirically testing the impact of electrification is connection cost vouchers. In Ethiopia, Bernard and Torero (2009) randomly distributed vouchers worth 10 and 20 percent of the connection cost. They found that households receiving a 10 and 20 percent voucher were, respectively, 11.0 and 12.8 percentage points more likely to connect to the grid, after controlling for a range of other factors. They also found that the vouchers proved most successful in less poor households that could afford the remaining costs not covered by the voucher. They concluded that subsidies should be targeted to the 75 percent poorest households, recognizing that the poorest households still will not be able to connect to the grid. Moreover, the authors concluded that the distribution of vouchers should be limited to households within a certain range of the lines in order to keep connection costs in check. In El Salvador, Barron and Torero (2014) ran a similar trial in which they randomly allocated 20 and 50 percent vouchers to households to pay for part of the required inspection fee. They found that vouchers increased the probability of connection by 11 to 19 percentage points, respectively, and that the difference between the two voucher amounts was not statistically significant. In a randomized controlled trial (RCT) in Kenya, Lee et al. (2016b) found households receiving a 100 percent subsidy of the connection fee were 95 percentage points more likely to connect to the grid than those paying the full amount. However, smaller subsidy amounts of 57 percent and 29 percent led to only 23 and 6 percentage point increases in connection rates, respectively, compared to those in the control group. Take-up rates in these lower-subsidy groups were, not surprisingly, higher among wealthier households (Lee et al. 2016b).

Lower connection costs for households may also be achievable by decreasing a utility's cost of expanding the grid and installing new lines. In particular, Golumbeanu and Barnes cite several cost-saving strategies such as the use of smaller transformers and smaller-gauge lines, a reduction in the number of poles, the use of cheaper materials for poles, and implementation of a variety of other technical changes.[2] Karhammar et al. (2006) provide examples of countries that experimented with cost-saving strategies and found that they could use lower cost materials without compromising quality or durability. For example, Tunisia replaced traditional concrete poles with round iron poles that were not only cheaper but also lighter (reducing transportation costs) and less fragile. In general, many African countries use distribution standards that are far above what is needed for the low density and low demand characterized by rural areas. Cost savings can be achieved by installing systems tailored to the needs and demand of specific areas.

E. Benefits of electrification

In this section, we present evidence from studies that attempt to estimate the impacts of electricity on household outcomes. Many studies on the impact of electricity suffer from issues of selection bias. By simply comparing connected to nonconnected households or electrified villages to non-electrified villages, studies may overstate any impacts by failing to distinguish between/among households or villages along other important dimensions such as income, household composition, education, and so on. Recently, several studies (Dinkelman 2011; Bensch 2011; Barron and Torero 2014, 2016; Bernard and Torero 2009; Khandker et al. 2009; Khankder et al. 2012) have relied on more rigorous evaluation designs such as random allocation of vouchers, instrumental variables (IVs), and matching techniques. However, the number of such studies is still fairly small. In this review, we attempt to highlight where rigorous methods have been used but also present descriptive evidence especially when more rigorous information is lacking. An overview of these studies, the methods used, and their findings are presented in Table II.2.

[2] These may include single-wire earth-return systems; shield wire systems; and single-phase medium-voltage and minimum low-voltage network systems.

1. Timing of connections

Much of the current research, particularly research that attempts to attribute causality, reports on results after a relatively short period. Little is known about how long it takes households to connect after electricity becomes available in their community, but it could take several years for households either to save enough money to pay the connection cost or, if the demonstration effect is true, to understand the benefits. Furthermore, delays may occur where utilities lack the materials, staff capacity, and incentive to connect households, particularly in rural areas characterized by tariff rates that are often below the marginal cost of providing electricity.

Unfortunately, most reports on the impact of new electricity lines did not specify when the lines were built in a given community. In addition, almost none of the studies followed a fixed set of households over time. For these reasons, it is difficult to measure how connection rates change with the construction of new lines. However, the information that does exist may still be informative for comparison and for planning purposes. Using the information available from four studies we reviewed, we developed a graph of estimated connection rates by year after installation of grid electricity (Figure II.1). We describe the graph below as we discuss the relevant studies.

An MCC-funded evaluation of a rural electrification project in El Salvador suggested that connection rates increased from zero to around 45 percent in the first year after village electrification and then increased by more than 80 percent over the following three-year period, from the end of the first year in which connections were made until four years after connections were made. The study was unique in that it tracked individual households and thus avoided counting households that may have moved into the community after construction of the electricity lines. The authors followed 500 households over a four-year period, from 2009 (before the lines were built) to 2013 (Barron and Torero 2016). They found that connection rates rose from around 45 percent in the first year after the construction of the lines to around 66 percent after two years and around 82 percent after four years (top line in Figure II.1).

Data analysis of a World Bank-funded grid extension program in Lao People's Democratic Republic (Lao PDR) found that about half of all households connected to the grid in the first year after the village was connected (World Bank 2008b). Connections slowed markedly after the first year, with 64 percent connected after three years and 74 percent after 10 years. Findings were similar in a World Bank study in the Philippines—50 percent of households connected within two years, but 20 percent remained unconnected after 20 years (World Bank 2008a). These studies are represented by the middle two lines in Figure II.1. We assume that the connection rates in these two studies and in the Tanzania study discussed below included in-migrants who did and did not connect to the grid.

Table II.2. Summary of research studies on benefits of electrification

Study	Country	Intervention	Estimation method	Location	Sample size	Findings by domain: Connection rates	Energy use	Education	Health & safety	Time use	Economic	Mobility
Lee et al. 2016a and b	Kenya	Impact of being offered a subsidy covering 100%, 57%, or 29% of the connection fee	Randomized encouragement design	Rural	2,500 households	+						
Barron and Torero 2014; Barron and Torero 2016	El Salvador	Impact of receiving a voucher to cover 20 or 50 % of the connection fee.	Randomized encouragement design	Rural	500 households	+	+	+	+	+	+	
Bernard and Torero 2009; Bernard and Torero 2015	Ethiopia	Impact of receiving a voucher to cover 10 or 20% of the connection fee.	Randomized encouragement design	Rural	800 households	+	o			o	o	
Van de Walle et al. 2015	India	Impact of being connected (as determined through IV)	IV - distance to nearest power producing plant	Rural	6,000 households			+			+	
Grogan and Sadanand 2013	Nicaragua	Impact of having electricity in the home (as determined through IV)	Fixed effects with IV - land gradient and 1971 municipal population density	Rural	950 households					+	+	
Chakravorty et al. 2013	India	Impact of being connected as determined through IV (also, impact of having a high-quality connection)	IV - differences in density of transmission cables from the national average	Rural	9,791 households						+	
Lipscomb et al. 2013	Brazil	Community level - impact of county electrification as determined through IV	Fixed effects with IV - predicted grid rollout based on geography and cost.	Rural and urban	2,184 counties			+	o		+	
Khandker et al. 2012	India	Impact of being connected (as determined through IV)	Fixed effects with IV- proportion of households in village with electricity	Rural	24,000 Households		+	+	+		+	
Bensch et al. 2011	Rwanda	Impact of household being connected to the grid. Data collected at one point in time.	DID with PSM	Rural	537 households		+/o	o			o	

Table II.2. *(continued)*

Study	Country	Intervention	Estimation method	Location	Sample size	Findings by domain: Connection rates	Energy use	Education	Health & safety	Time use	Economic	Mobility
Dinkelman 2011	South Africa	Community level - impact of village being electrified, as determined through IV; impact of change in fraction of households with electric lighting over time.	IV - land gradient; household-level fixed effects model	Rural	1,816 communities		+				+	+
Khandker et al. 2009a	Bangladesh	Impact of being connected (as determined through IV)	IV - whether or not household is within 100 feet of the line; PSM	Rural	28,000 households			+			+	
Khandker et al. 2009b	Vietnam	World Bank-funded rural electrification project - expanding electrification to rural villages	DID with fixed effects and a matched comparison group	Rural	1,120 households			+			+	
Barkat et al. 2002	Bangladesh	Compares outcomes of households connected to the grid to non-connected households in both communities with and without electricity access	Unadjusted comparison of outcomes between connected and non-connected households	Rural	2,491 households		+	+	+		+	
ESMAP 2002	Philippines	Compares outcomes of electrified and non-electrified households	Regression analysis	Rural	2,000 households	+						
Wamukonya and Davis 2001	Namibia	Compares households connected to the grid and households with solar power to households with no electricity connection	Unadjusted comparison of outcomes between groups	Rural	371 households		+/o		+	+	o	o

Note: This table summarizes the studies we reviewed that attempt to quantitatively estimate the impacts of electricity access or electricity connections on household and community outcomes. The studies are listed in chronological order of publication date, with most recent study first. Findings are summarized according to the interpretation of the authors. For instance, a statistically significant decrease in indoor air pollution is designated with a plus sign, as this is seen as a positive impact of electricity access. Semi-colons in the "Estimation Method" column indicate separate analyses.

+ Study finds beneficial, statistically significant impacts

o Study does not find statistically significant impacts, though some findings might be large in magnitude if the standard errors were large

+/o Study examines a number of outcomes in the domain and finds beneficial, statistically significant results for some, but not all, outcomes.

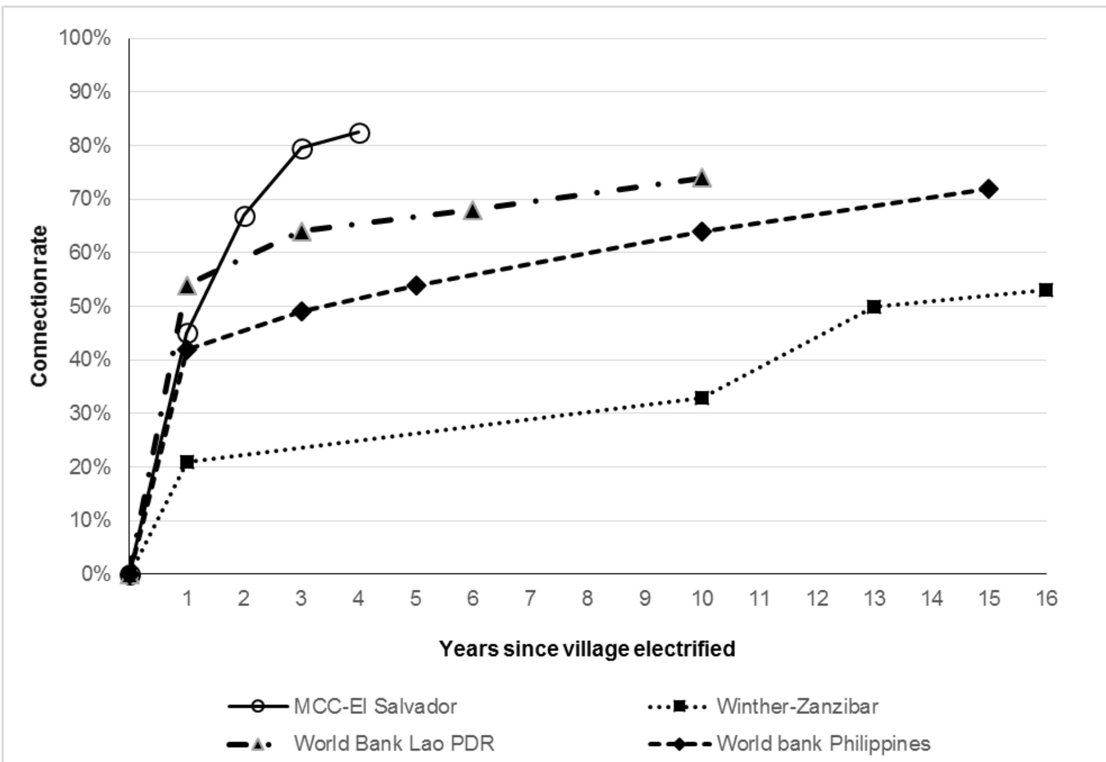
DID Difference-in-differences

IV Instrumental variable

PSM Propensity score matching

The final study on the topic of timing covers a village in Zanzibar over a 13-year period (1991 through 2004) starting in the year after the lines were built. The study provided data on the connection rate in the community in each study year. In contrast to the other studies reviewed here, the connection rate reached only 21 percent in 1991, one year after village electrification (bottom line in Figure II.1). About 10 years later (in 2001), the rate had risen only moderately, to 33 percent. At the time of the study, 16 years after electrification, slightly more than half of households were connected (Winther 2007). Another study in Western Kenya (not shown in the figure) found similarly slow connection rates, with only about 10 percent of households with high-quality walls connected five years after the funding and installation of a transformer in the community (Lee et al. 2016a)[3].

Figure II.1. Estimated connection rates by year after grid installation



Source: Barron and Torero (2016) for MCC-El Salvador; Winther (2007) for Zanzibar; World Bank (2008b) for Lao PDR; and World Bank (2008a) for Philippines.

Notes: The MCC study followed the same households across the years. We assume the remaining three studies included in-migrants in the counts of connected households. Circles and triangles represent data points. For MCC-El Salvador, we took the average of the rates for the treatment and control groups. For Winther (2007), we estimated the last two numbers (in years 13 and 16) based on text in the report and assume that the denominators are the total number of households in each respective year, including all in-migrants regardless of connection status. For the two World Bank studies, data points are estimated based on figures and text in the reports. Both studies measure the connection rate as the fraction of total households in electrified villages that are connected to the grid.

[3] Connection rates from this study are excluded from Figure II.1 because the study reported connection rates separately for households with high-quality walls (made from brick, cement, or stone) and households with low-quality walls (made from mud, reed, wood, or iron), and did not provide exact numbers.

Together these studies suggest that in some contexts connection rates may increase slowly over time, and that a long period of time is necessary to observe the full impact of installing power lines. However, it is also important to keep in mind that the context, policies, and costs associated with grid extension varied across these projects. This likely had an effect on the speed with which households connected.

2. Timing of benefits to electricity customers

The above evidence shows that it may take many years for some households to connect to the grid and that few studies measure connection rates over time. Similarly, once households connect to the grid, they might not fully realize the benefits of electricity over the short term. Therefore, in this section, we review the evidence on the timing of the benefits of connecting to electricity. We found only a few studies that addressed the issue directly and many that addressed it indirectly. Overall, the literature seems to show that it may take several years for electricity to have an impact on household-level outcomes.

Two studies authored by Khandker et al. (2009a) and Khandker et al. (2009b) address the timing issue directly, suggesting that impacts are likely to continue increasing for several years following the introduction of electricity in an area. Khandker et al. (2009a) used propensity score matching and distance to a grid line as an instrument for a household being connected to the grid to examine the effects of electric connections on income, education, and expenditure in rural Bangladesh. The researchers found that household electricity consumption increased by about 5 kWh per month for every five years the household was connected to the grid. They also separated households into categories based on duration of exposure and found that while household income increased with duration, it did so at a decreasing rate and the benefits level off after eight years. A similar study in Vietnam (Khandker et al. 2009b) revealed no clear trend in income based on years of exposure but did show a steady increase in school enrollment by years of exposure, with a particularly large jump between households connected for zero to two years versus those connected for two to four years.

The studies that indirectly addressed the timing issue did not look at timing per se but estimated impacts after a specific number of years. By comparing studies that estimate impacts over different time periods, we can observe the length of time needed for impacts on household outcomes to manifest. One study—Bernard and Torero (2009)— examined the impacts of an electricity connection voucher program in Ethiopia only one year after implementation and found no clear effects of the vouchers on household expenditures, income, or time allocation.

The remaining literature looked at longer-term outcomes—from three to nine years after the introduction of electricity—and generally found positive impacts. Bensch (2011) investigated differences in a number of outcomes between villages with and without electricity in Rwanda. The mean duration of connection among households in the villages with access to electricity was five-and-a-half years. Bensch found a statistically significant increase in lighting hours, but the impacts on child studying time, energy expenditure, and income were not robust to regional differences. Dinkelman (2011) used a district fixed-effects model in South Africa with land gradient as an instrument for project placement. Within five years after the installation of electricity lines, treatment areas had a 23 percentage point increase in the share of households using electric lighting, a 4.2 percentage point decrease in the share of households using wood to cook, and a 13.5 percentage point increase in female employment. Chakravorty et al. (2014)

estimated impacts associated with a 16 percent increase in connections to the grid in India between 1994 and 2005. They found that non-agriculture incomes in rural households connected to the grid increased by 9 percent over the period as compared to nonconnected households. Finally, using a randomized encouragement design with vouchers to reduce the cost of electricity connection in El Salvador, Barron and Torero (2014) found that, three years after introduction of the vouchers, treatment households were 34 percentage points less likely to experience high air pollution levels (measured in fine particulate matter with a diameter of 2.5 micrometer or less [$PM_{2.5}$]) and 16 percentage point less likely to have had a child experience an acute respiratory infection (ARI) in the last month. They measured a 59 percent reduction in exposure to $PM_{2.5}$ for men and 33 percent for women, which equates to a 33 and 25 percent reduction in risk of lung cancer for men and women, respectively. They found no clear impact on years of schooling or enrollment but did find a 7 percentage point increase in the likelihood of the child studying at home and an average increase of 10 minutes per day of studying.

3. Impacts of connecting

a. Energy use

Many studies have demonstrated that households in rural areas of developing countries use electricity primarily for lighting, transitioning away from kerosene, but they rarely use electricity for cooking or for productive uses (Bernard and Torero 2015; Bernard 2012; Barron and Torero 2016). These studies have measured energy use through the ownership and use of light bulbs and appliances as well as through the types of fuel used, often indicating changes in lighting and cooking.

The findings indicate that the impacts of connecting to electricity on lighting are strong. A rigorous study in South Africa found that connection to the grid resulted in a 71 percentage point increase in the use of electric lighting while a descriptive study in one electrified community in Zanzibar found that 99 percent of electrified households own at least one light bulb (Dinkelman 2011; Winther 2007). In Rwanda, 91 percent of connected households reported that lighting was the main advantage associated with electricity (Bensch 2011). In the same study, connected households owned, on average, about two light bulbs and experienced 13 more hours of lighting per day than nonconnected households, as estimated through a nonexperimental design. A rigorous study in India found that households connected to the grid used 35 percent less kerosene than those not connected (Khandker et al. 2012), while another experimental study also found a large, statistically significant decrease in the percentage of households using kerosene (Barron and Torero 2016). However, both kerosene and candles may still find use in the case of outages or to illuminate rooms without a light bulb (Wamukonya 2001). Indeed, a simple comparison of electrified and non-electrified households in the Philippines found that 56 percent of electrified households reported using kerosene lighting, compared to 91 percent of non-electrified households (ESMAP 2002).

The limited capacity of the electricity connection may constrain household energy use. A study in Ethiopia found that the connection available in 87 percent of connected households allowed for no more than four light bulbs (Bernard and Torero 2015). The capacity of the connection likely varies substantially by country, but it has major implications for what additional benefits can be derived from electrification. In South Africa, the default home supply allows the operation of a television, radio, two lights, and several small kitchen appliances (Dinkelman 2011).

Some evidence points to the increased purchase of appliances beyond light bulbs when households get connected to the grid. According to the World Bank's Independent Evaluation Group, television is the second most common use of electricity after lighting; almost half of electrified households have a television (World Bank 2008). The study in the Philippines found that 75 percent of electrified households owned a television and estimated through regression analysis that electrified households listened to the radio and watched television for 1.91 hours and 2.25 hours more per day, respectively, than non-electrified households (ESMAP 2002). In a non-rigorous comparison of means in Ethiopia, the fraction of households that owned a mobile phone, radio, television, and refrigerator increased more over time in connected households than in nonconnected households, though rates of refrigerator ownership remained very low at less than 2 percent (Bernard and Torero 2009).

b. Cooking and fuel use

It is generally assumed that, given the opportunity, households will move up the "energy ladder," replacing traditional biomass fuels with modern fuels (Heltberg 2003). In practice, evidence on the impact of electricity on fuel use is mixed. Indeed, researchers have only rarely observed changes in the fuel used for cooking. An exception is Dinkelman (2011), who found in a fixed effects model that connected households in South Africa moved away from wood and to electricity for cooking. A non-rigorous study in Namibia found that only 14 percent of connected households shifted to electricity as the primary cooking fuel, and many electrified households either did not own electric stoves or limited their use because of relative cost (Wamukonya 2001). Overall, the amount of firewood used in electrified households was no less than that used in non-electrified households. Numerous other studies, both quantitative and qualitative, have found no change in wood use or cooking practices (Bernard and Torero 2009; Barron and Torero 2016; Winther 2007). In Tanzania, interviews revealed that men preferred the taste of food prepared with firewood while women cared less about taste and were more interested in the potential time savings associated with an electric stove. The women did express concern about the safety of cooking with electricity (Winther 2007). Furthermore, the author suggests that the men, who paid for the electricity in most cases, did not want to pay for electricity for cooking when firewood was available at no cost.

In Nicaragua, only 22 percent of electrified households in the rural study communities owned any type of cooking stove (Grogan and Sadanand 2013). It is interesting to note, however, that the study found a difference in fuel use between urban and rural households. The authors reported that only about 10 percent of electrified households in rural areas use modern fuel for cooking versus 58 percent in urban areas (Grogan and Sadanand 2013).

c. Education

Electricity may benefit children through reducing the time they spend collecting fuel and by allowing them to study longer at night and with better light. Numerous studies have attempted to estimate the impact of household electrification on children's time use and educational outcomes, and they generally find positive impacts.

A study in Bangladesh using propensity score matching to estimate the impacts of electricity on a number of household-level outcomes found that both boys and girls in connected households studied for longer periods and completed more years of schooling than those in similar nonconnected households (Khandker et al. 2009a). Specifically, boys studied 18 more minutes per day and completed 0.28 more years of schooling in electrified households than in nonelectrified households. Similarly, girls in electrified households studied 17 minutes more per day and completed 0.23 more years of schooling than those in nonelectrified households. Other studies have shown similarly positive results. In Vietnam, a study using propensity score matching and a fixed effects model found that electricity increased school enrollment of boys and girls and increased the number of school years completed for boys (but not for girls) (Khandker et al. 2009b). In India, a study using an IV approach found that school enrollment increased by 6 percent for boys and 7.4 percent for girls as a result of household electrification. Children in electrified households also studied, on average, one hour more per week than those in nonelectrified households (Khandker et al. 2012). Another study in India using an IV identification strategy found that grid electricity connection increased school enrollment rates and years of schooling for girls (Van de Walle et al. 2015). In Rwanda, one study using difference-in-differences (DID) and matching found that electricity increased child study time; however, this result was not consistent across all models (Bensch 2011).

d. Time use

The introduction of electricity into the home is expected to have an impact on household member's time use. For example, electric lighting may allow people to work or study longer into the evening and it may free up time by reducing the burden of certain household chores. Although several studies measured household member's use of time over the course of a day, they did not always measure it in the same way or with the same categories. Therefore, it is hard to draw general conclusions across the studies.

Regression analysis in a study in Nicaragua found that both men and women in electrified households spent about an hour less per day collecting firewood than men and women in nonelectrified households (Grogan and Sadanand 2013). A rigorous study in India found that both men and women spent 3.3 fewer hours per month collecting biofuels if they resided in a home with electricity (Khandker et al. 2012). In contrast, results from a randomized encouragement design in Ethiopia found no clear impacts of a voucher for a discounted electricity connection on self-employed work, household chores, child care, "time on self," homework, entertaining visitors, or watching television and listening to the radio (Bernard and Torero 2015). In Namibia, members of households with grid electricity reported that they were able to extend their day, particularly teachers who were able to use electric lighting to prepare their lessons (Wamukonya 2001).

e. Health and safety

Electricity might have impacts on health and safety (both real and perceived) along several dimensions. Anecdotally, households with electricity report feeling safer and appear to be better informed about public health issues. Not many studies attempt to estimate the direct impact of household electrification on child and adult health; however, one recent rigorous study finds statistically significant large reductions in indoor air pollution and incidence of child ARI in households that receive a voucher for a discounted connection (Barron and Torero 2016).

In Namibia, 87 percent of households reported that they felt safer at night once they connected to the grid (Wamukonya 2001). World Bank research in Bangladesh and Kenya found that clinics with electricity are open for one hour longer per day, on average, compared to nonelectrified clinics (World Bank 2008). In Bangladesh, one study found that electrified households were more likely to have a television and, as a result, greater knowledge of public health issues (Barkat et al. 2012). World Bank analysis of Demographic and Health Survey data in 11 countries found access to TV increased health and family planning knowledge, after controlling for household, individual, and community characteristics (World Bank 2008).

Electricity may also have a major health impact through reducing indoor air pollution produced by solid fuel and kerosene use in the home. Pollution from solid fuels has been linked to ARI, chronic obstructive pulmonary disease, lung cancer, asthma, perinatal conditions and low birth weight, and vision problems including blindness (Ezzati and Kammen 2012). The World Health Organization (WHO) estimates that 4.3 million people die prematurely each year from causes related to indoor air pollution (WHO 2016).

A recent study in El Salvador was one of the first to estimate causal impacts of electricity on indoor pollution and resulting health impacts. The study measured $PM_{2.5}$ concentration throughout the day and night and collected time-use data from different household members in order to match time use with indoor pollution rates. The research found that, one year after the introduction of electricity, households that had received a voucher for a discounted connection cost had 67 percent lower overnight $PM_{2.5}$ concentrations than households that did not receive a voucher (Barron and Torero 2016). The same study also found that children under age 6 were 34 percentage points less likely to suffer from an ARI. These impacts seemed to stem from a large decrease in kerosene use as households moved to electric lighting. However, cooking practices did not change, and, as a result, women had a lower reduction in exposure than men and children in the household. Further, these findings may not be applicable to other settings, as fuel use varies by country and region. Findings from Bensch et al. (2015) suggest that African countries may not experience the same dramatic reduction in kerosene use found in other regions because kerosene is already being replaced by dry cell batteries in nonelectrified households.

Despite this evidence of improved health outcomes from transitioning to electricity use from other household fuels, increased electricity production also has an environmental cost, especially if it involves a large increase in consumption of energy produced by fossil fuels. Although hydroelectric power plants have historically produced the majority of Tanzania's electricity, the country is rapidly shifting to coal and natural gas (World Bank 2016). Thus, any expansion of the electricity grid that relies on these energy sources will come with a corresponding impact on greenhouse gas emissions and climate change.

Coal combustion adds to greenhouse gas emissions through the production of methane, carbon dioxide, and other air pollutants, and it also produces coal combustion residuals that harm the environment if not properly managed (National Research Council 2010). Although natural gas releases fewer pollutants, it still produces measurable amounts of carbon dioxide and methane. Even renewable power sources have an external cost associated with the production and use of the equipment. A study estimating the average external cost of different fuels in Europe found that coal had the largest external cost, at 3.14 Euro cents per kWh (Markandya 2010). Natural gas had a cost of 1.39 Euro cents/kWh, and hydropower from a dam cost just

0.08 Euro cents/kWh. A study conducted by the U.S. National Research Council estimated that damages to human health and the environment (not including climate change) are valued at 3.2 U.S. cents/kWh for coal combustion emissions and at only 0.16 U.S. cents/kWh for natural gas production (National Research Council 2010). The study also produced climate damage estimates of 1—10 cents/kWh for coal, and 0.5—5 cents/kWh for natural gas, dependent on the estimated social cost of carbon. Another study on electricity supply externalities in South Africa found that the overall cost to society of increased greenhouse gas emissions was far greater than the overall cost of damages from local air pollution (Spalding-Fecher 2005). Finally, a study using an IV to estimate the impacts of electrification at the county level in Brazil found no statistically significant impact on life expectancy, suggesting that the health benefits of electrification may be offset by increases in pollution (Lipscomb et al. 2013).

f. Business activity and economic well-being

A recent study in Nicaragua using an IV approach found that women in electrified households were substantially more likely to work outside of the home than those in nonconnected households (Grogan and Sadanand 2013). The results reflect the behavior of women age 20 to 35, who are 28 percent more likely to work outside the home if they have electricity. The study showed no statistically significant effect on men's work outside of the home. In Namibia, households with electricity were no more likely to be involved in an income-generating activity (IGA) than those without electricity (Wamukonya 2001). In addition, few IGAs used electricity or, if so, only for lighting.

One IV evaluation in India found large economic effects of electricity. The study showed that electricity increased women's employment hours by 17 percent and men's by only 1.5 percent (Khandker et al. 2012). In addition, it showed that, in electrified homes, household per capita income increased by 39 percent and total expenditures by 18 percent while the poverty rate decreased by 13.3 percentage points. However, the study found that the impacts on income and expenditures were greater for rich households; those in the 15th and 25th expenditure percentiles experienced no clear impacts, but those in the 85th percentile experienced an expenditure increase of 30 percent because of electricity. Another study in India using an IV approach found that nonagricultural incomes of electrified rural households were about 55 percent higher than those of nonelectrified households and that an increase in the quality of electricity led to an even greater increase in nonagricultural incomes (Chakravorty 2014).

Bernard and Torero's (2009) randomized encouragement design found no clear impacts of receiving a voucher for a discounted connection on household expenditures, income source, or time allocated to IGAs in Ethiopia. In Bangladesh, results from an analysis using propensity score matching showed an 8.2 percent increase in per capita expenditures and a 12.2 percent increase in overall total income associated with getting grid electricity (Khandker et al. 2012). In Vietnam, a matched comparison group study found that connection to the grid increased household total income by 25 percent and increased per capita expenditure by almost 10 percent (Khandker et al. 2009). Dinkelman (2011), using an IV approach in South Africa, found that villages with electricity access had a female employment rate that was about 9 percentage points higher compared to villages without access and that there was an unclear effect on male employment.[4] She also found that women in the middle quintile and second-richest quintile achieved the largest employment gains. In another study using an IV, Lipscomb et al. (2013) found that county electrification in Brazil led to a large and statistically significant increase in the county's Human Development Index score, an increase that was driven by estimated increases in average household income and education.

In India, Van de Walle et al. (2015) used an IV model to estimate internal household effects of connection to the grid as well as external effects of being an unconnected household in an electrified village. The study found that residence in a connected village increased nonconnected households' annual consumption growth rate by 0.8 percentage points and led to a shift away from food expenditures to other expenditures (Van de Walle et al. 2015). The study also found that households connected to the grid had higher consumption levels than nonelectrified households.

g. Composition and mobility

In a non-rigorous study in Namibia, researchers found that electricity was not related to migration: about four percent of households had had someone migrate to an urban area, and about the same percentage had had someone return to the community since electrification (Wamukonya 2001). Dinkelman (2011) found substantial migration out of the study districts (all rural), but the rates did not differ by land gradient (the IV). However, under the IV specification, she did find that, over five years, the population in the treatment communities grew by 400 percent more than the population in the control communities (Dinkelman 2011).

Several of the studies reviewed here may have captured results that reflect changes in the composition of the community via migration rather than changes at the level of the individual household (Khandker et al. 2009a, 2012; Dinkelman 2011), though at least a few studies did use methods that enabled them to isolate impacts on households (Barron and Torero 2016; Bernard and Torero 2014; Khandker et al. 2009b).

h. Conclusion

This review has shown that although the last decade has brought a marked increase in the number of rigorous studies that attempt to estimate the causal impact of household electrification on household well-being, the literature is still fairly limited. In addition, much of what does exist focuses on impacts of rural electrification on poverty, education, health, and the environment. There is a dearth of rigorous research on the impact of electrification on a mix of urban, peri-urban, and rural areas, which is the case for the Tanzania energy sector project. This evaluation will begin to fill this gap by presenting rigorous evidence on the impact of household electrification in urban, peri-urban, and rural areas.

[4] A linear probability model suggested the point estimate for women was more than double that of men (13.6 percentage points versus 4.1 percentage points). However, the results were much more similar in a logistic model (23.6 and 21.5 percentage points) and neither gender difference was statistically significant.

CHAPTER III

EVALUATION DESIGN

This page has been left blank for double-sided copying.

In this chapter, we present our central research questions, major aspects of the evaluation designs, and the outcome domains of interest for the evaluation.

A. Evaluation questions

The key research questions addressed in our analysis are as follows:

- What are the impacts of being in communities selected to receive new electricity lines through the T&D activity?
- What are the impacts of being in communities selected to receive low-cost connections to the electric grid through the FS initiative?
- What are the impacts of being connected to the national electric grid?
- Do impacts vary by gender, age, income, or urbanicity?
- What types of nonexperimental evaluation designs are best at producing impact estimates similar to an experimental design in the context of this evaluation?

In addressing these research questions and assessing impacts as described above, we focus on short-term outcomes (such as connection rates), intermediate outcomes (such as time spent on studying at night, and on watching television), and longer-term outcomes (such as poverty rates). We cover a variety of outcome domains, including energy use, education, health, safety, time use, economic well-being, and mobility. For the full list of outcomes we assess, see Table III.2 and III.3.

Answers to these questions provide important information for policy purposes. Answers to the first question, on the impacts of T&D lines, can help inform policymakers about the potential benefits of the Power Africa initiative, which is designed to increase the availability of electricity throughout the continent of Africa—an initiative that will necessarily involve building far more lines than currently exist, especially in rural and peri-urban areas, similar to where the MCC lines were built in Tanzania. Answers to the second question, on the FS initiative, relate to initiatives aimed at subsidizing electricity access. Given the low average income levels throughout the continent, similar initiatives may be needed in other countries to enable households to take advantage of new lines. Answers to the third question, regarding the benefits of connections to the grid, could help future researchers simulate the potential benefits of providing electricity when they have data only on connection rates and not on other outcomes. Answers to the fourth question, on variation in impacts across subgroups, will be useful for policymakers considering the welfare implications of electrification for different segments of the Tanzanian population. Finally, results for the last question, regarding nonexperimental designs, will be useful for policymakers considering the benefits of more rigorous evaluation methods. To summarize, by addressing these key research questions, we will amass evidence that can guide future electricity projects and long-term policymaking.

B. Impact evaluation design

In Table III.1, we summarize the technical approach for an impact evaluation of the T&D line extensions, the FS initiative, and the exploratory analysis of impacts of connecting to the grid. We also briefly discuss a number of other closely related questions that could be addressed using these data in future research.

Table III.1. Technical approach to impact evaluation

Intervention	Evaluation methodology	Intervention/ treatment group	Comparison/ control group	Outcome domains
T&D line extension	Difference-in-differences (DID) method, comparing changes in outcomes over time between T&D intervention and matched comparison group	Households, businesses, and communities in areas that received line extensions	Households, businesses, and communities in matched areas that did not receive new line extensions	Connection rates[a] Energy use Education and child time use Health and safety Business and adult time use Economic well-being Composition and mobility
FS initiative	Random assignment of areas either to a treatment or control group; comparison of outcomes between these two groups at follow-up	Households in areas that received the T&D lines and the FS low-cost-connection offers	Households in areas that received the T&D lines but did not receive the FS offers	
Connecting to the electric grid	DID method, comparing changes in outcomes over time between connected and matched nonconnected households	Households that connected to the national electricity grid	Households that did not connect	

[a] The connection rates domain is used only for the T&D and FS evaluation questions.

1. Matched comparison group evaluation design for T&D line extensions

We are using a DID method with a matched comparison group and pre-post data to estimate the impacts of extending electricity lines to the new areas covered by the T&D lines. We compare outcomes for the intervention group with outcomes for the comparison group measured at follow-up (about two years after the lines were built), and control for baseline characteristics, including the baseline value of the outcome when available, which were measured well before the new lines were built.[5,6] We used propensity score matching to select the comparison group communities and households to ensure their similarity to the intervention group communities and households. We captured the outcomes by using baseline and follow-up surveys of households and communities conducted, respectively, before and after completion of the line extensions.

---

[5] For the evaluation of the T&D lines, we refer to the areas that received the line extensions as the intervention group. A subset of that group received offers of low-cost connections through the FS initiative. We refer to that subset as the treatment group.

[6] The T&D lines component was also implemented in a seventh region—Kigoma. However, given that Kigoma was not initially part of the T&D activity, it did not participate in the baseline surveys such that the T&D evaluation does not cover that region. The communities that received T&D lines in Kigoma are included in the FS initiative evaluation as reflected in data from the follow-up survey.

We selected households in the comparison group that match those in the intervention group. To that end, we first identified all communities in the targeted regions, covering both those that were expected to receive new lines through the T&D activity, and others that were not. We then used propensity score matching—a statistical method to match on multiple factors (Rosenbaum and Rubin 1983)—in three stages to select the communities and households that were used for the T&D lines impact analysis. The matching approach provides us with a comparison group that is as similar as possible to the intervention group on observed characteristics. In the context of the T&D activity, the most theoretically important observed characteristics are community size and distance to the nearest capitol. Similar variables were explicitly used to determine which communities would receive the T&D lines. More precisely, the goal was to estimate costs and benefits of extending the lines with costs estimated using distance from existing lines and benefits estimated using numbers of potential customers. The community size and distance to the nearest capitol are proxies for these variables that were available in our data. The additional matching variables used in our analyses should help to adjust for the fact that we had to use proxies for the actual selection variables.

More specifically, we started with a 2002 census list of over 6,000 communities in the six regions of Tanzania targeted for the T&D lines in 2008. We combined the list with information from TANESCO to identify the 337 communities that were scheduled to receive the T&D lines. We took a random sample of 182 of the 337 communities, which constitutes the intervention group of the evaluation. We then implemented propensity score matching in three stages to identify the comparison communities in those regions and comparison households within those communities. In the first stage, we identified three potential comparison communities for each intervention community, applying nearest-neighbor matching with replacement. NRECA International (NRECA), the firm contracted by MCA-T to carry out the baseline surveys for the evaluation, then implemented a community survey in the 182 selected intervention communities and the 546 potential comparison communities. In the second stage of propensity score matching, we used the community survey data and applied a matching-without-replacement method to identify one matched comparison community for each intervention community. We then took stratified random samples of households from each community targeting only households that were not connected or within 30 meters of an existing line. NRECA then conducted a survey of these households in the 182 intervention communities and 182 comparison communities.[7,8] Finally, we used the data from the baseline community and household surveys for a third and final stage of matching of households in the intervention and comparison groups. Chaplin et al. (2015a) describe the first two stages of matching while, in Appendix A, we provide a detailed discussion of the final stage of matching.

[7] We obtained complete data for the 182 intervention communities. The NRECA field team could not access three of the comparison communities in Morogoro because they were inaccessible as a result of bad road conditions after heavy rain. Those communities were not considered as potential matches in the later stages of our matching.

[8] After completion of the baseline household surveys, we learned from MCA-T and TANESCO that 4 of the 182 surveyed intervention communities were no longer targeted to receive new lines under the T&D activity. Consequently, we excluded these communities from the evaluation, bringing the total number of intervention communities to 178.

In Chaplin et al. (2012), we presented differences between the intervention and comparison groups means for over 200 variables. We found that the percentages of the differences that were statistically significant at various significance levels were consistent with what would be expected by chance alone. To help ensure that these remaining differences did not lead to biased estimates of impacts, we use regression adjustment for other covariates in this report. Key control variables include the baseline measures of the outcome when available. This regression adjustment might also have increased precision of the DID estimates by eliminating extraneous variation attributable to those covariates (see, for instance, Rubin 2007; Imai and Van Dyk 2004; Robins and Rotnitzky 2001; Rubin 1973).

2. Random assignment evaluation design for FS initiative

We used a random assignment evaluation design to estimate the impacts of being in a community that was offered low-cost connections through the FS initiative. The FS initiative was implemented for two reasons. First, it helped to address concerns that connection costs were too high for most households to afford at least in the short run. Second, it provided an opportunity to use a randomized controlled trial evaluation to help inform future work in this area. The FS initiative was available only in the communities covered by the T&D line extensions. The initiative covered all six regions in the T&D lines evaluation as well as the Kigoma region, which was not in the original design and was later added. Therefore, the evaluation of the FS initiative is closely related to the evaluation of the T&D lines, as illustrated in Figure III.1. With the exception of the part of the FS sample in Kigoma, we selected both the treatment and control groups for the FS initiative evaluation from among the intervention communities for the T&D lines evaluation. In a public event on July 16, 2012, we randomly assigned 29 communities to the treatment group that received the FS initiative[9] out of a total of 192 communities—178 in the six regions covered by the T&D lines evaluation and another 14 communities in Kigoma. The remaining 163 intervention communities (192 minus 29) constitute the control group that was not offered low-cost connections. Mathematica hired a communication firm, Camco, to inform the 29 communities about the offer of low-cost connections and to encourage households to consider taking advantage of the offer.

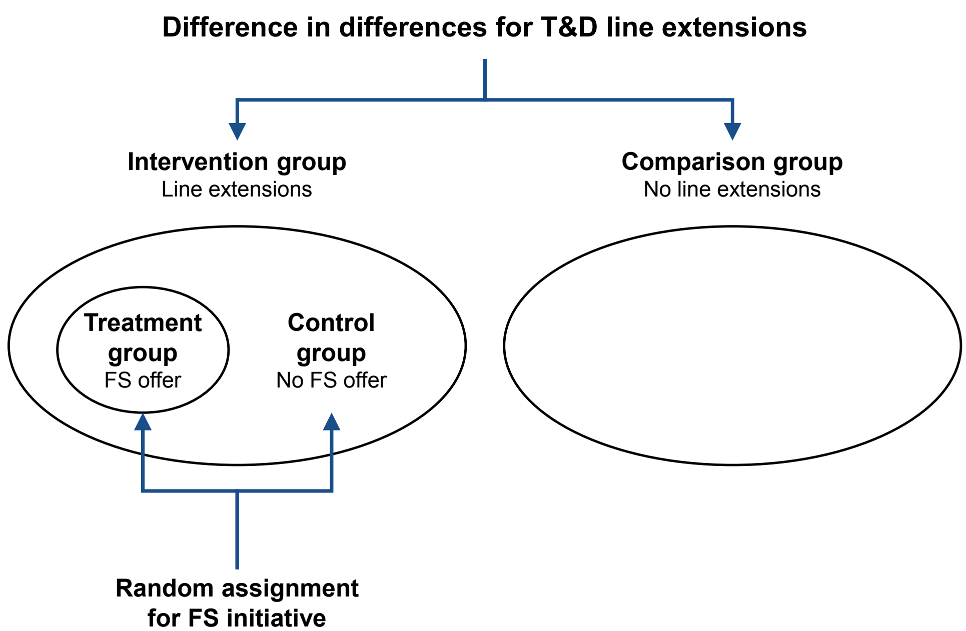
The evaluation design for the FS initiative had implications for the evaluation of the T&D lines. Our estimates of the overall impacts of the T&D lines are affected by the fact that 15 percent of those communities (27 out of 178) also received the low-cost-connection offers and related communications campaign.

[9] At that event, we assigned a total of 30 communities to receive the FS initiative. Each community had the same probability of being sampled, but we stratified the sample by size and region, with the 16 largest communities in one stratum and the remaining communities split by region. Two of the communities were located in the Kigoma region, which was not covered by the T&D baseline surveys but was covered by the follow-up surveys. In addition, one community randomly assigned during the public event to receive the FS initiative was one of the four communities mentioned earlier that, at the time, were no longer targeted to receive the MCC-funded lines. MCA-T made the decision not to provide new lines to the one community as well as to the three other intervention communities before random assignment. Consequently, dropping these four communities does not create any bias in the estimated impacts of the FS initiative. The study includes communities that later changed status.

3. Exploratory analysis of impacts of connecting to the national electric grid

We carried out an exploratory analysis of the impacts of connecting to grid electricity on household outcomes because the impacts of the T&D lines on connection rates were much smaller than originally assumed. We recommended the exploratory analysis to MCC after reviewing data from the follow-up household listing compiled between May and July 2015, which suggested that the impacts of residing in a T&D community on household connection rates were much smaller (only about one-quarter as large in percentage point terms) than projected at baseline, indicating that the impacts of the T&D lines on household outcomes would be greatly diluted. Consequently, our ability to detect statistically significant impacts on other household outcomes of interest was considerably lower than expected at the time we developed the initial evaluation design report (Chaplin et al. 2011) and the baseline report (Chaplin et al. 2012).

Figure III.1. T&D evaluation: Overlap of T&D line extensions and FS initiative



To address this concern, we conduct an exploratory analysis of impacts of connecting to grid electricity on household outcomes using data from households in all study communities (that is, both the intervention and comparison communities). Using propensity score matching, we compare outcomes of connected households (in either T&D communities or comparison communities) observed in the follow-up household survey with outcomes for a matched set of not-connected households. In Appendix A, we provide a detailed technical discussion of the matching.

Even though the estimated impacts on household outcomes from the exploratory analysis are likely to be larger than those from impact analysis of the T&D lines, they may also be biased because of unobserved differences between the connected and nonconnected households. To help address the possibility of bias, we used an IV approach to estimate the impacts of connection to the grid and to test for bias in the results from our main exploratory analysis models. The IVs were based on the FS initiative status and on TANESCO rules regarding how far a house can be from a pole to be connected to the grid without any additional poles. As shown in Appendix H we find no clear evidence of bias based on the IV models. It should be kept in mind, however, that the IV results could differ from the results based on matching for another reason—that the IV results are only applicable to subset of households whose decisions to get connected were affected by the IV. If impacts for these subset of households differ from the overall impacts on those who connected in ways that are similar to the bias in our matching models, then our tests for bias may be misleading. However, we have no *a priori* reasons to believe that this would be the case.

In theory one could estimate the impacts of T&D lines and the FS initiative on various outcomes by multiplying their impacts on connection rates with the estimated impacts of being connected on the same outcomes. This will not work if the estimated impacts of being connected are biased, and/or if there is spillover of benefits of T&D lines and the FS initiative to nonconnected households. In addition the estimated impacts of T&D lines and the FS initiative on many outcomes may appear to not align with the estimated impacts of being connected simply because of estimation error. Readers should keep these possibilities in mind when interpreting our results.

The exploratory analysis provides MCC with information to simulate longer-term benefits of the current T&D interventions. This could be done by combining data showing impacts of the T&D lines on connection rates in later years, when impacts on those rates may be higher than they are now, with the estimates in this report showing benefits of connecting. Thus, if in the future TANESCO is able to provide MCC with accurate and reliable data on connection rates in the study communities, MCC can use those data to estimate longer-term impacts of T&D lines on connection rates, and then multiply those estimates by the estimated impacts of being connected on other outcomes from our exploratory analyses. These estimates would be less rigorous than those specified by the current design for estimating impacts of T&D lines on household outcomes because they will ignore spillover and differential impacts by type of households. However, use of the results from this exploratory analysis to simulate longer-term benefits could be highly cost-effective as compared to collecting data on all outcomes in the future.

Another potential benefit of the exploratory analysis of impacts of connections on household outcomes is that it provides information that can enhance future evaluations in situations where it is possible to obtain data on connection rates but not on other household outcomes. That is, the estimated impacts of connections to the electric grid on household outcomes from our exploratory analyses may be combined with estimated impacts on electricity connections related to other interventions. Hence, this exploratory impact analysis provides valuable information that might be relevant to several energy sector interventions considered by other development partners in Tanzania, and by MCC and other funders in similar countries.

4. Related questions not addressed in this report

There are a large number of other closely related research questions that could be addressed with the data from this evaluation. Even though these are potentially important questions, it would distract from the focus of our study if we presented all of the possible comparisons in a single report, and weaken our ability to thoroughly cover the research questions mentioned earlier in this chapter. For these reasons we focused on the research questions listed above and estimate the impacts of the T&D lines, the FS initiative, and of being actually connected to the grid. Other potential questions include the following:

a. What are the benefits of T&D lines and the FS initiative combined compared to neither? We could address this by comparing outcomes for the FS treatment group with outcomes from our T&D comparison group. These estimates would likely be somewhat larger than those reported for T&D lines or the FS initiative but smaller than those of actually connecting.

b. What are the benefits of T&D lines without the FS initiative? Our current estimates of the impacts of T&D lines incorporate impacts of the FS activity for the 27 T&D communities that received the low-cost connections offers. To isolate impacts of new lines without the FS initiative we could compare outcomes from the FS control group that was targeted to receive new T&D lines but not the FS initiative, with the T&D comparison group. These estimates would likely be similar to those of T&D lines since the FS initiative affected only a small fraction of the T&D sample.

c. What are the benefits of being in a community that received new MCC lines? We could address this by comparing outcomes of households in communities that received the new MCC lines with outcomes of a matched set of households from communities that did not receive MCC lines. These estimates would likely be larger than those found for our evaluation of the impacts of T&D lines since we included all communities targeted for new MCC lines even if they did not end up getting those lines. The impacts would likely be smaller than the benefits of actually being connected.

d. What are the benefits of being in a community that received any new lines? We could address this by comparing outcomes of households in communities that received any new lines with outcomes of a matched set of households in communities that received no new lines. These estimates would differ from the estimated benefits of receiving new MCC lines since many communities received non-MCC lines.

e. What are the benefits of gaining access to new lines? We could address this by comparing outcomes of households with access (that is, those within 30 meters of a new line) to outcomes for a set of households that was selected to be similar but that did not have access. These estimated impacts would likely be similar to but smaller than the estimated impacts of actually being connected.

f. What are the benefits of living in a community with lines but not connecting? We could address this by comparing outcomes for households that were not connected but were in communities with lines to outcomes of similar households in communities without lines. It is hard to predict what these estimates might look like but one might expect to see positive impacts on outcomes where spillover is likely—for example on perceptions of safety at night since light from electrified households may make people in nearby houses without electricity feel safer at night.

5. Benefits of more rigorous evaluation designs

We test to see whether certain design elements of nonexperimental methods can help to reduce bias. To estimate how much these design elements affect bias, we use an approach called a within-study comparison that compares estimated impacts from an RCT—in our case the RCT used to estimate impacts of the FS initiative —with those from various nonexperimental designs that vary the design elements used. We vary three design elements—controlling for the baseline value of the outcome variable, matching on a rich set of additional covariates, and using local geographic comparisons.

C. Outcomes for impact analysis: Primary and secondary outcomes by domain

MCC implemented the T&D activity and FS initiative in order to reduce poverty and promote overall household wellbeing. Our evaluation was designed to test whether or not these goals were achieved by looking at short-, intermediate- and longer-term outcomes related to these goals. We look at both household and community level outcomes and cover a wide range of domains designed to provide a holistic picture of the impacts of these interventions.

Given that we estimated impacts on a large number of outcomes, we remained mindful of the statistical problem of "multiple comparisons." When researchers estimate impacts on a large number of outcomes, they are likely to see that at least a few of the estimates are probably statistically significant by chance, even if no true impacts occurred. We took a balanced approach to addressing the multiple comparisons problem (Schochet 2009) by making a tradeoff between reducing the likelihood of getting "false positives" (that is, finding statistically significant impacts by chance even when no true impacts exist) and maintaining our ability to avoid "false negatives" (that is, the statistical power to avoid incorrectly inferring no impacts when true impacts exist). First, we determined a parsimonious set of outcome domains and specified one or a few primary outcomes in each domain. The primary outcomes provided the basis for tests of the main hypotheses. By limiting the number of main hypotheses to be tested, this approach reduces the likelihood of finding impacts by chance alone, without substantially undermining the evaluation's statistical power to detect true impacts. Second, we estimated impacts on a large number of secondary outcomes in each domain, but we interpreted the estimated impacts on the secondary outcomes cautiously, highlighting the findings only for the supplementary outcomes if we found a credible pattern of statistically significant impacts on them.

Guided by the conceptual framework for the Tanzania energy evaluation, the evaluation design report (Chaplin et al. 2015) identified the domains and primary outcomes to be examined in the impact analysis. In Tables III.2 and III.3, we present the primary outcomes we analyzed by domain from our community and household surveys, respectively, followed by a sample of the secondary outcomes. We examined outcomes in seven domains: (1) connection rates, (2) energy use, (3) education and child time use, (4) health and safety, (5) business activity and adult time use, (6) economic well-being, and (7) community composition and household mobility. Within each domain we specified a few outcomes as primary and a larger number as secondary. These are used for the T&D lines, FS initiative, and exploratory analyses. For the T&D analysis we also have community-level outcomes. We did not estimate impacts of the FS initiative on community-level outcomes because the FS initiative was implemented for only one sub-village within each village covered by the community survey, whereas the T&D lines were installed across multiple subvillages within each village. We did not estimate impacts of being connected on community-level outcomes because being connected varied within community in both the intervention and comparison groups. All outcomes are described in detail in Appendix C.

The first two domains (connection rates and energy use) cover short-term outcomes. The first domain, connection rates, is the domain in which we expect the largest positive impacts. The primary outcomes at both the community and household levels are the connection rates themselves. At the community level this means the connection rate for all households in the village or *mtaa* (urban neighborhood). At the household level this means the connection rate for households that were eligible for the baseline survey—meaning that they were not within 30 meters of a pole or connected at baseline. Thus, the household-level outcome refers to a group of households for which we would expect larger impacts than at the community level. Our secondary outcomes in this domain at the community level all relate to access to electricity from different sources. The secondary outcomes at the household level in the connections rate domain cover the type of pole a household is connected to (MCC-funded or funded by another entity), access to the grid, distance from a pole, years connected to a pole, and hours per day with electricity.

Table III.2. Community data: Primary and secondary outcomes by domain

Domain	Outcomes
Connection rates[a]	
Primary outcomes	Fraction of households connected to grid (based on community survey)
Secondary outcomes	Fraction of households (1) connected to, (2) within 30 meters of the grid (based on follow-up household listing); Community has access to (1) national grid; (2) isolated grid; (3) generator; or (4) solar, windmill, or other electricity sources
Energy use	
Primary outcomes	None (see household survey outcome)
Secondary outcomes	TANESCO informed households fully or partially about low tariff requirements; community has access to (1) kerosene, (2) diesel/gasoline, (3) firewood, charcoal, or dung
Education and child time use	
Primary outcomes	Community has electrified school(s)
Secondary outcomes	Distance from community to nearest (1) preprimary, (2) primary, and (3) secondary school
Health and safety	
Primary outcomes	Community has electrified health facility (dispensary, health center, diagnostic laboratory, hospital)
Secondary outcomes	Community has health facility open at night; distance from community to nearest health facility; distance from community to obtain (1) vaccination, (2) X-ray, (3) malaria test, (4) HIV test; community has light available on a cloudy night; perceived safety of female residents at night; perceived safety of male residents at night; most community members have piped water; community has a police post
Business and adult time use	
Primary outcomes	Community has at least one electrified business
Secondary outcomes	Community has electrified businesses by type (repair shop, tea/coffee shop/guest house/hotel, and weekly market); fraction of establishments in community electrified (all businesses, weekly market, agricultural equipment repair shops, restaurant/tea/coffee shops; carpentry shops, mills, mobile money banking, and so forth); community has electrified post office; community has farming, fishing, livestock, or hunting as the main source of income
Economic well-being	
Primary outcomes	Price of residential land per acre
Secondary outcomes	Price of farming land per acre; community is one where most people have mobile phones; community has new facilities, built after 2011: (1) school, (2) water supply, (3) health center, and (4) roads; community has plans for new or upgraded (1) school, (2) water supply, (3) health center, (4) roads, and (5) market
Composition and mobility	
Primary outcomes	Number of households in community (household listing)
Secondary outcomes[b]	Fraction of current households newly formed since 2011; fraction of current households that are in-migrants since 2011; community identified as village at follow-up; community boundaries changed since 2011

[a] The connection rates domain is used only for the T&D and FS evaluation questions.

[b] The first two secondary outcomes in the composition and mobility domain are based on data from the household listing data and cover the subvillage or *mtaa*. The remaining outcomes are based on the community survey and cover the village or *mtaa*.

Table III.3. Household data: Primary and secondary outcomes by domain

Domain	Outcomes
Connection rates	
Primary outcomes	Household is connected to national grid
Secondary outcomes	Household is connected to MCC lines; household is connected to non-MCC lines built after October 2011; household is connected to non-MCC lines built before October 2011; household has access to grid without additional poles (based on household survey response); household is within 30, 40, 50, and 100 meters of nearest electric pole; average years household has been connected to national grid; hours per day household has grid electricity
Energy use	
Primary outcomes	Amount of electricity used by household from any source; amount of liquid fuel (kerosene, diesel, gas, LPG) used by household
Secondary outcomes	Household uses electricity from any source except batteries; household owns a generator powered by liquid fuel/solar/hydro/wind; monthly amount of grid electricity used by household; monthly amount of nongrid electricity used by household; monthly amount of kerosene used by household; monthly amount of solid fuel (wood, crop residue, straw/leaves, dung, charcoal, candles) used by household; number of electric tools and appliances owned by household; household owns a television; monthly hours of electric tools and appliances used by household; monthly hours of electric fan used by household; monthly amount of light (in lumen-hours) consumed by household; total monthly cost of light; household owns at least one mobile phone; monthly household costs for mobile phone recharge
Education and child time use	
Primary outcomes	Average hours per day children (age 5 to 14) spend studying at night
Secondary outcomes	Average hours per day children (age 5 to 14) spend in total studying; average hours per day youth (age 15 to 24) spend studying at night; average hours per day youth (age 15 to 24) spend in total studying; time children (age 5 to 14) spent on collecting water and fuel in last 24 hours; time children (age 5 to 14) spent on other household chores (washing clothes, cleaning, and so forth) in last 24 hours; time children (age 5 to 14) spent in leisure/entertainment in last 24 hours; time children spent watching television in last 24 hours; time children spent sleeping at night in last 24 hours; fraction of children (age 5 to 14) in the household currently attending school; household has children (age 5 to 14) attending a school with electricity
Health and safety	
Primary outcomes	Fraction of youth (age 15 to 24) in household with health problems in last 7 days; fraction of children (age 5 to 14) in household with health problems in last 7 days
Secondary outcomes	Household has a member age 15 to 24 who missed work in the last 30 days due to illness; pollution per month from soot; pollution per month from CO2; household received any information about family planning from television, radio, internet, or telephone in last 30 days; household currently uses any family planning method; household received any information about HIV/AIDS from television, radio, internet, or telephone in last 30 days; household ever visited a hospital at night; respondent feels safe by (1) all measure of safety (sufficient communal light, feel safe walking, and safe from crime and animals), (2) one measure of safety, and (3) more than half of the measures of safety; household had a fire in home since 2011; household had a fire caused by electric source since 2011; household had a fire caused by nonelectric source since 2011

Table III.3. (*continued*)

Domain	Outcomes
Business and adult time use	
Primary outcomes	Household operates any income generating activity (IGA)
Secondary outcomes	Household operates any IGA that uses grid electricity; household's monthly and yearly revenue from IGAs; households has any member who is a paid employee; Each of the following outcomes was measured separately for men and women, over the past 24 hours: Time spent on wage labor (agriculture and nonagriculture); time spent on nonwage productive activities (farming and other activities); time spent on other IGAs; time spent on collecting fuel and water; time spent on cooking and food processing; time spent on other household chores and child care; time spent on education-related activities (reading/studying); time spent on socializing, resting, and other leisure activities; time spent at home with family; time spent on watching television; time spent sleeping at night
Economic well-being	
Primary outcomes	Household total nonelectricity consumption
Secondary outcomes	Household income; per capita daily consumption; per capita daily income; household lives on less than $1 per day per person and less than $2 per day per person (based on consumption); total household assets; household lives in an electrifiable dwelling based on wall and roof materials; number of rooms in household for sleeping; household has a flush toilet; household has piped water in both rainy and dry seasons
Composition and mobility	
Primary outcomes	None
Secondary outcomes	Household moved within community since 2011; baseline household moved out of the community since 2011; baseline household with less than district-level median income has moved out of the community since 2011; baseline household with more than district-level median income has moved out of the community since 2011; household size; number of children in household

The second outcome domain is energy use. We also expected large and positive impacts on some outcomes in this domain—for example total electricity consumed. We had no primary outcomes in this domain at the community level. The secondary outcomes at the community level are related to whether or not households were made aware of the requirements to obtain the low-tariff rates available to households that use little electricity and the types of non-electric fuel the community has available. At the household level, the primary outcome is the amount of electricity used. Secondary outcomes relate to use of alternative fuels and sources of electricity; amounts of electric and non-electric fuels used by source; appliance ownership and use; and light use and costs. Households reported on their use of electricity and non-electric fuels in terms of the number of hours that they used each of these. In order to construct some of the outcomes in this domain, we relied on constants collected from various external sources. For example, we calculated the number of lumen-hours of light produced by light-producing devices, as well as the number of kWh (for electricity), kilograms (for solid fuel), and liters (for liquid fuel) consumed in one hour of use of each of these energy sources. These constants are described in detail in Appendix D. Specifically, we calculated the total lumen-hours of light consumed by a household based on their hours of consumption of energy sources for light and external information about the lumen-hours of output of each of these sources, as well as the total monthly cost of light and the cost per lumen. We also relied on external information about the number of kWh produced by various electricity sources to calculate the total amount of kWh produced monthly by a household's electricity sources and the kWh of non-grid electricity that a household consumed monthly. Finally, we used external information to calculate the total kilograms of solid fuel and total liters of liquid fuel that a household consumed in a month.

Domains three through five cover intermediate outcomes. The third domain is education and child time use. The primary outcome at the community level is whether or not the community has an electrified school. The secondary outcomes at the community level describe distance to different types of schools (preprimary, primary, and secondary). At the household level the primary outcome is average hours children age 5 to 14 spent studying at night in the last 24 hours. The secondary outcomes at the household level cover hours children spent doing various activities and the fractions of children attending any school and an electrified school. For approximately 20-30 percent of our sample, children's time use over the last 24 hours adds up to less than 24, possibly because adult respondents did not know how their children spent all of their time.

The fourth outcome domain is health and safety. The primary outcome at the community level is whether the community has an electrified health facility. The secondary community-level outcomes cover whether the facilities are open at night, the distances to different types of facilities, perceived safety, piped water, and presence of a police post. At the household level the primary outcomes cover the health status of youth, specifically whether youth experienced any health problems in the last seven days. The secondary household-level outcomes cover adult health, pollution, knowledge about health issues such as HIV and family planning, health behaviors, perceived safety, and fires. We relied on conversion factors collected from external sources to calculate the amount of pollution produced by soot and carbon through households' use of various energy sources.

The fifth outcome domain is businesses and adult time use. The primary community-level outcome in this domain covers electrified businesses. The secondary community-level outcomes cover the availability of various types of businesses and services that are electrified and main income sources. At the household level, the primary outcome is the fraction of households with an IGA. The secondary outcomes cover whether the IGAs are electrified, their revenues, if any household member has a paid job, women's time use in the last 24 hours, and men's time use in the last 24 hours. Respondents could report overlapping activities for their time use, so their total time use could add up to more than 24 hours in one day. In addition, because we excluded some activities from our calculations of time use, a respondent's total time use could also add up to less than 24 hours in one day. Specifically, we omitted bathing/personal hygiene, religious practices, time spent with other family members, time spent at home during the day, and time spent at home during the evening. These were assumed to overlap substantially with the other specific categories.

The sixth outcome domain is economic well-being, which is our main long-term outcome and of particular interest to MCC for calculating economic rates of return. The main outcome in this domain at the community level is the natural log of the price of residential land in the community.[10] Secondary community-level outcomes cover the price of farmland, various public

[10] We focus on land values from the community survey for two reasons. First, many households may see little short-term benefits of new lines in terms of income especially for those households that cannot afford to connect to the new lines. However, their property values should increase even if they cannot benefit in other ways. Second, our community-level measure of land prices covers property of people who left the community while our household-level data does not capture such property. Thus, our community-level land price measure is more appropriate than the household-level measure.

services, and plans for new services. The primary outcome at the household level in this domain is non-electric consumption. Secondary household-level outcomes cover income, consumption and assets.

The final outcome domain covers the community composition and household mobility. New electric lines may encourage people to move into a community and current residents to stay. The primary outcome at the community-level is the number of households. We would expect this to be positively impacted by the T&D lines. Secondary community-level outcomes cover if the community is considered rural, if the boundaries have changed since 2011, in-migration rates, new household formation rates, and mobility within the community. We have no primary outcome at the household level in this domain. Secondary outcomes at the household level cover in-migration rates, new household formation rates, and out-migration rates by baseline income. We hypothesized that when communities get new lines the price of residential land might rise. This, in turn, could encourage low-income households to sell their land and move elsewhere, and higher income households to remain so that they could take advantage of the new lines.

Finally, we also estimate impacts by subgroup. The subgroups considered include the gender and age of the household head, rural-urban status of the community, and household income. We look at gender because there is a great deal of interest in reducing inequality by gender. Evidence that impacts are positive and larger for women would suggest that similar interventions might have beneficial impacts on gender gaps in outcomes like use of electricity, earnings and business ownership. Evidence that impacts are larger for men might suggest that additional work is needed to help ensure that such interventions do not exacerbate existing inequities. We look at variation by age, focusing on whether or not the head of the household was under the age of 25 at the time of the baseline survey based on the argument that households with a younger head might be in a better position to move and thereby take advantage of new electric lines. We look at rural-urban differences based on the hypothesis that people in urban areas might be in a better position to take advantage of new electric lines, both because they might have more income which would enable them to afford the connection costs and because they might have more exposure to other households with electricity and thus a greater appreciation of the potential benefits. We look at variation by income by grouping households based on the quartile of baseline household income. This is done to help determine what types of households (for example, relatively poorer or richer households) appear to take advantage of the T&D lines and FS low-cost-connection offers and appear to benefit most.

CHAPTER IV

DATA SOURCES AND ESTIMATION APPROACH

This page has been left blank for double-sided copying.

In this chapter, we describe our methods for sampling, data collection, and analysis. We conducted sampling at both the community and household levels. We collected community-level data, listing data (to create a sampling frame for the household survey), and household survey data. Our analysis plan covers methods used to estimate impacts of the T&D lines, the FS initiative, and being connected to the electricity grid (the exploratory analysis).

A. Sampling

For the T&D and FS evaluations, we used data from the baseline and follow-up community and household surveys conducted for the evaluation. In this section, we describe the sampling strategies for the surveys.

1. Sampling for the baseline community survey

The baseline community survey targeted 182 intervention communities and 546 potential comparison communities in six regions of Tanzania.[11] The primary sampling unit (PSU) for the community survey was a village (*kijiji*) in rural areas and an *mtaa* in urban areas.[12] We selected the rural and urban communities covered by the baseline community survey in three steps. First, the evaluation team worked with MCA-T and TANESCO to finalize a list of communities (villages or *mitaa*) that were likely to receive new lines; we identified 337 communities (Table IV.1).[13] Second, we randomly selected 182 of those villages and *mitaa* to represent the intervention communities in the evaluation. The number achieved the desired level of precision, as explained in our design report (Chaplin et al. 2011a). Third, as mentioned in Chapter III, we identified 546 potential comparison communities by using propensity score matching with existing census and Global Positioning System (GPS) data. We selected the potential comparison communities from among all of the nonintervention communities in the same region. In Table IV.1, we present the distribution of the intervention and potential comparison communities across the six regions in mainland Tanzania where the T&D lines was implemented. The numbers of sampled intervention and potential comparison communities have the same distribution across regions as the total population of intervention communities, as shown in Table IV.1.

[11] Kigoma was excluded at baseline because it was not part of the T&D lines activity at that time.

[12] The Swahili word *kijiji* (plural *vijiji*) means village and refers to a rural administrative unit; *mtaa* (plural *mitaa*) translates to street and refers to the smallest urban administrative unit. Villages may be further subdivided into subvillages (*vitongoji*, singular *kitongoji*), which is the smallest rural administrative unit. Given that the English word street could give rise to confusion about a geographic area, we use the Swahili words *mtaa* or *mitaa* throughout the report to refer to the urban communities in the evaluation. For the rural communities, we use villages and subvillages to refer to *vijiji* and *vitongoji*, respectively.

[13] The 337 villages and *mitaa* on our list were divided into 182 subprojects. Subprojects are units used by MCA-T and the implementing entities building the lines.

Table IV.1. Number of intervention and potential comparison communities for the community survey by region

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Intervention villages/*mitaa*				Nonintervention villages/*mitaa*		
Region (as of 2008)	Total number of villages/ *mitaa*	Total number	Percent of total	Number sampled	Percent of total sampled	Total number	Number sampled for community survey	Percent of total sampled
Dodoma	658	73	22	39	21	585	117	21
Iringa	1,017	37	11	20	11	980	60	11
Mbeya	1,330	21	6	11	6	1,309	33	6
Morogoro	1,009	74	22	40	22	935	120	22
Mwanza	1,186	55	16	30	16	1,131	90	16
Tanga	1,269	77	23	42	23	1,192	126	23
Total	**6,469**	**337**	**100**	**182**	**100**	**6,132**	**546**	**100**

Note: The number of potential comparison communities in column 8 equals three times the number of intervention communities in column 5.

2. Sampling for the baseline household survey for the T&D evaluation

We conducted the baseline household survey in 182 intervention communities and 182 matched comparison communities.[14] For the household survey, we used a *mtaa* in urban areas as the PSU. In rural areas, when a village encompassed several subvillages, we used a subvillage (*kitongoji*) as the PSU; otherwise, we used the village as the PSU. In the intervention group, for a village encompassing several subvillages, we selected the subvillage with the largest percentage of households expected to have access to the new T&D lines (as reported by the community survey respondents in the baseline community survey).[15] In each comparison village encompassing several subvillages, we selected a subvillage that was matched to the population rank of the corresponding intervention subvillage. The purposive selection of the subvillage as the PSU in rural areas allowed us to achieve a much higher proportion of households in the sampling frame with likely access to the new lines than we would have achieved if we had used the village as the PSU. Without the purposive selection of subvillages, the evaluation would have required a much larger sample of households to ensure reasonable confidence in detecting impacts. We did not need to identify a smaller PSU in urban areas because we expected that, in urban areas receiving new lines, almost all households would have access once the new lines were built.

[14] During the baseline household survey, we had to replace seven comparison communities because all households in those communities were located within 30 meters of existing lines or were already connected and not eligible for the survey. We collected community-level data longitudinally and thus, at follow-up, administered the household survey in communities covered by the baseline household survey.

[15] Here, access to the electricity lines implies that the household may connect without purchasing an additional pole and generally means that the household is located within about 30 meters of the new low-voltage lines.

Given the selection of intervention communities with a high percentage of households likely to have access to the new lines, we understand that results from the evaluation do not generalize to households in communities in which a small fraction of households has access to electricity. However, to guide policy decisions about future electrification, it is preferable to focus on communities with better access to new lines; future projects will likely build on the T&D activity and, over the long term, move closer to providing access to electricity for most or all households. Consequently, estimating impacts for communities where a greater percentage of households has access to electricity is more policy-relevant than estimating impacts for subvillages characterized by only a small fraction of households with access.[16]

For the baseline household survey, in addition to identifying the communities of interest, we had to sample households. For each intervention and comparison community (village, subvillage, and *mtaa*) selected for the baseline household survey, we created a list of all households residing in the community and used the resultant lists to produce the sampling frame for the household survey. The data collection firm worked with knowledgeable community representatives to identify locations of households within each community. For the intervention communities, we developed the lists of households during the fielding of the community survey; for the comparison communities, we developed the lists the day before the household survey was administered in a particular community.[17] The method of compiling the lists could have affected the comparability of households in the intervention and comparison groups if large fractions of households moved during the months between administration of the community and household surveys to the intervention group. However, our analysis (reported in Chaplin et al. 2012) suggests that only a fairly small percentage of intervention group households moved during this time, and their movement did not have a noticeable impact on the comparability of households in the two groups.[18] The list for each community also identified whether a household was already

[16] In estimating impacts of the T&D lines, we use weights to adjust for sampling, nonresponse, and matching so that the estimated impacts represent impacts on household outcomes in communities in which large fractions of households are receiving the new T&D lines (Angrist and Pischke 2009, pp. 91–92; Pfefferman 1993).

[17] The difference in the timing of the household listing in the intervention and comparison communities is attributable to several reasons. The community and household surveys were conducted in the same intervention group communities. Consequently, for the intervention group, NRECA was able to carry out the household listing and the community survey at the same time. Moreover, we needed to identify households with small (no more than two rooms) versus large houses for a planned subsidy-pilot activity in the intervention communities and therefore needed to oversample subsidy-eligible households. As a result, the listing of households in the intervention communities had to be completed long before the fielding of the household survey. After the baseline survey, the subsidy-pilot was replaced by the FS initiative, which did not target small households. For the comparison group, we conducted the community survey in three times as many communities as the household survey and used data from the community survey to select the communities where the household survey was administered. Consequently, it was not possible to undertake the household listing at the same time as the community survey.

[18] In our analysis of the baseline data, we found that approximately 3 percent of the sample had moved in the last 7.5 months. This may be an underestimate of actual mobility because the household listing and survey could have been conducted a few months apart in the intervention group. In the comparison group, where the listing and survey were completed within a few days of each other, about 4.8 percent had moved in the last 7.5 months. To test for the possibility that the difference in the timing of the listing in the intervention and comparison groups could have created a lack of balance in the number of mobile households in each group, we dropped households in both groups that had been in their communities for less than 7.5 months. The results were very similar to the results obtained when these households were not dropped, suggesting that differential migration between the listing and survey did not contribute to a lack of balance between the intervention and comparison groups.

connected to the grid or located near an existing line.[19] Given that we did not expect households already connected to the grid or located close to an existing line to connect to the new lines, we excluded such households from the household survey sampling frame, though a handful were electrified by the time of the baseline survey. The remaining households on each list constituted the sampling frame for each community.

In both the intervention and comparison communities, we sampled the same fraction of households from each PSU, meaning that we interviewed more households in the larger communities.[20] Within the intervention group communities, we oversampled households residing in a small house (they were under consideration for a targeted subsidy- pilot activity that was not implemented), as discussed in Appendix A.[21]

3. Sampling for the follow-up community and household surveys

At follow-up, we conducted the community survey in communities located in the original six regions and a seventh region—Kigoma. The follow-up community survey targeted 178 intervention communities and 182 matched comparison communities from the original six regions.[22] As noted in Chapter III, given that Kigoma was not initially part of the T&D activity, we did not conduct any baseline surveys there; consequently the evaluation of T&D lines does not cover that region. The follow-up community survey, however, covered 14 communities from

---

[19] According to data we received from TANESCO, about one-third of the intervention communities where new lines were under development already had lines. TANESCO provided us with these data to help us develop a sampling frame for communities in the intervention group.

[20] In theory, we could have achieved more precise results if we had randomly sampled communities proportional to their size and then sampled an equal number of households in each community (Lohr 1999). However, we lacked data on subvillage size when we drew our sample of villages and *mitaa* for the community survey. We could have sampled villages instead of subvillages, but the data on village size were outdated (from the 2002 census). In addition, based on the baseline community survey data, we estimated that only about 33 percent of the households in the target villages would have access to the new lines compared to about 69 percent of the households in the subvillages that we selected for the household survey. Thus, selecting subvillages with high access was expected to more than double the estimated fraction of households with access to the new lines in our sample of intervention group villages.

[21] More precisely, in the intervention group, we sampled households by using explicit stratification according to whether the house had more than two rooms and by using implicit stratification by community and gender of the household head (information that was available on the listing form). In the comparison group, we conducted explicit stratification by community and simple random sampling within the community. The methods differed for two reasons. First, the FS initiative was not implemented in the comparison group so there was no need for stratification by number of rooms in the home. Second, we did not know who would be drawing the comparison group sample when we came up with the sampling plan because MCA-T was hiring the data collection firm. Hence, we wanted to minimize the chances for error.

[22] After we collected data from the baseline surveys, MCA-T and TANESCO determined that 4 intervention communities sampled for the evaluation would no longer receive new MCC-funded electric lines. We dropped those 4 communities from the follow-up surveys, bringing the sample size down from 182 intervention communities in the baseline surveys to 178 in the follow-up surveys (excluding Kigoma). The original 182 comparison communities and 182 intervention communities were not equivalent at baseline, and dropping the 4 intervention communities who did not receive MCC-funded lines did not change this. However, because we matched individual comparison and intervention households for our analysis (as described in Section C), the lack of balance in intervention and comparison communities was not a concern.

Kigoma. Using data from the follow-up survey, the FS initiative evaluation included communities in Kigoma that received T&D lines.

For the follow-up household survey, we targeted the same 10,908 households that we sampled at baseline, including those that we sampled at baseline but that did not respond to the baseline survey and those that migrated out of the study communities; we excluded 139 households that we sampled at baseline but that we found to be deceased, merged with other households, or duplicates at the time of the follow-up survey. We used this baseline sample for our main analyses of the T&D initiative and used the intervention group sample for our main analyses of the impacts of the FS initiative.

The FS initiative was also implemented in Kigoma. However, without baseline data for Kigoma, we could not obtain a sampling frame guaranteed to be exogenous. Hence, we treat the Kigoma sample separately when estimating FS impacts. We sampled households in 14 communities in Kigoma that received T&D lines, 2 of which were randomly selected to receive the FS initiative. To create a household sampling frame, we created lists of all households in the sampled Kigoma communities at the time of the follow-up survey. During the listing process, we identified the households residing in the sampled Kigoma communities before October 2011 (at about the time of baseline survey administration in the other regions) and sampled them for the FS initiative evaluation. We sampled a total of 527 baseline households in the Kigoma communities as part of the follow-up household survey.[23]

4. Sampling for the "new-household" survey

Recognizing that decisions to migrate into a community or to form a new household could both be influenced by access to electricity, we wanted to assess whether the T&D lines or FS initiative affected outcomes for these types of households either because of selection or impacts on individual households. To that end, we created a sample of "new households"—in-migrant and newly formed households that are new in the study communities since the time of administration of the baseline survey. We collected data on new households so that we could examine outcomes for these households and assess impacts of the T&D lines and FS initiative on migration. We sampled the new households based on a list of households in each community that we created at the time of the follow-up community survey. However, as we found little evidence of impacts on in-migration and formation of new households within the community, we did very little with these data in this report.

In determining the sampling approach, we considered that we would be able to improve statistical precision of our estimates if we conducted the new-household survey in more communities (allowing us to account for clustering by community). For this reason, we oversampled households in communities with smaller numbers of households. We planned to sample, when possible, at least three in-migrant and three newly formed households per community and sample all in-migrant and newly formed households in communities with fewer than three such households. For communities with three or more new households, we also stratified by connection status within the community so that we sampled at least one connected and one nonconnected household when possible and proportionally allocated the sample across

[23] We also sampled new households in Kigoma. Those are covered in our new household section. We did not try to sample out-migrants in Kigoma.

these communities and strata unless there was no household in a stratum in that community. We proportionately allocated the sample between the two groups—in-migrant and newly formed households. Out of the total of 2,350 new households that we sampled, we arrived at 1,528 in-migrant and 882 newly formed households from 339 communities, reflecting the share of such households in the study communities.[24] This sample was designed to be representative of the population of in-migrant and newly formed households in the study regions once appropriate weights are applied. However, as explained below, during the follow-up household survey a large fraction of the households identified as in-migrants or newly formed in the listing told us that they were households in the community at baseline. This difference in reporting may have arisen from differences in community survey respondents' and household members' understanding of whether and when community boundaries changed (something that happened quite often). It may also reflect a lack of knowledge on the part of some community survey respondents, particularly those who were new or who were in communities with large amounts of in- and out-migration. The remaining new households (those that were identified on the listing and that self-identified as new) were a small fraction of the population, and so we made limited use of the data on this group in this report.

B. Data collection

Using the sampling strategy described above, we conducted a baseline and a follow-up survey at the community and household levels to support the evaluation of the T&D lines. MCA-T contracted with NRECA to conduct the baseline data collection activities. NRECA developed the survey instruments, with input from MCC, MCA-T, and Mathematica. For follow-up data collection, Mathematica subcontracted with Economic Development Initiatives Limited (EDI), a Tanzania-based data collection firm. In Table IV.2, we present summary information on the data collection activities at baseline and follow-up. The T&D baseline report (Chaplin et al. 2012) presents a detailed description of the data collection effort at baseline.

[24] There were 3,342 in-migrants and 1,966 newly-formed households in the follow-up listing in the communities sampled for the evaluation. These numbers are based on their status reported during the listing; as discussed in the text, many of these households reported that they were residing in the community at baseline.

Table IV.2. Purpose, target sample sizes, respondents, and timing of baseline and follow-up surveys for the Tanzania energy sector evaluation

Survey	Purpose	Target sample size	Respondent	Start and end date
Baseline surveys (Six regions: Dodoma, Iringa, Mbeya, Morogoro, Mwanza, Tanga)[a]				
Community survey	Collect community-level data at baseline; identify matched comparison communities for T&D evaluation	182 intervention, 546 comparison communities	Usually community leaders	April 18–May 28, 2011
Household listing	Create sampling frame for baseline household survey; in intervention communities, determine possible targeted subsidy-pilot eligibility[b]	182 intervention, 182 comparison communities	Community representatives	Intervention: April 18–May 28, 2011; Comparison: August–November 2011, 2 to 3 days before household survey[c]
Household survey	Collect baseline data on households	11,648 households in 182 intervention and 182 comparison communities	Key female and male members of household	August 15–November 20, 2011
Follow-up surveys (Seven regions: Dodoma, Iringa, Kigoma Mbeya, Morogoro, Mwanza, Tanga)[a]				
Community survey[d]	Collect community-level outcomes data for T&D evaluation	191 intervention, 180 comparison communities	Usually community leaders	May 25–July11, 2015
Household listing	Create a sampling frame for new-household survey	192 intervention, 182 comparison communities	Community representatives	May 25–July 11, 2015
Electric pole GPS location	Assess access to electricity in the study communities and support exploratory analysis	192 intervention, 182 comparison communities	Community representatives	May 25–July 11, 2015
Household survey	Collect household outcomes data	11,435 households in 192 intervention and 182 comparison communities	Key female and male members of household	August 31, 2015–January 27, 2016
New-household survey	Collect household outcomes among in-migrant and newly formed households	2,350 households in 192 intervention and 182 comparison communities	Key female and male members of household	August 31, 2015–January 27, 2016

[a] With Kigoma not initially part of the T&D activity, we conducted no baseline surveys there. At follow-up, we targeted 14 communities in Kigoma that received T&D lines; using data from the follow-up survey, we included these communities in the FS evaluation. Two contiguous communities in Kigoma merged such that we ended up with only 13 community surveys in Kigoma, though we still used the original boundaries to identify 14 communities for the listing data, the electric pole data, and the household survey in that region.

[b] Eventually, the targeted subsidy-pilot activity was not implemented.

[c] Because of the different timing of the baseline listing in intervention and comparison communities, we were concerned that any differences in the two groups may be due to the seasonal differences in data collection. The longer length of time between the listing and survey exercises in the intervention group also produced a lower baseline response rate in this group. These challenges are described in more detail in the T&D baseline report (Chaplin et al. 2012).

[d] These numbers differ from the baseline because two of the targeted comparison communities in Morogoro region merged with contiguous intervention communities by 2015 and two contiguous intervention communities in Kigoma merged with each other. We used baseline boundaries when collecting data from the other sources.

n.a. = not applicable.

1. Follow-up community survey

At follow-up, we conducted the community survey over a seven-week period between May 25 and July 11, 2015, targeting follow-up data collection to the same 178 intervention communities and 182 comparison communities included in the T&D evaluation and where we conducted the baseline survey. In addition, we surveyed 14 other communities in Kigoma that received T&D lines. During the community survey's fielding period, the data collection team found that two of the targeted comparison communities in Morogoro region merged with contiguous intervention communities; in addition, in Kigoma, two contiguous intervention communities merged with each other. Consequently, at the end, we collected data from a total of 371 communities—191 in the intervention group (including 13 in Kigoma) and 180 in the comparison group. With the merger of three communities with other communities, the effective response rate for the follow-up community survey was 100 percent. In Table IV.3, we present a breakdown of the number of communities at baseline and follow-up for the T&D lines and FS initiative evaluations.

Table IV.3. Community survey respondents for the T&D lines and FS initiative evaluations (target sample sizes in parentheses)

Group	Baseline survey	Follow-up survey
Total communities	**364 (364)**	**371 (371)[a]**
T&D evaluation (excludes Kigoma)[b]		
Intervention group	182 (182)[c]	178 (178)
Comparison group	182 (182)	180 (180)
FS evaluation		
Non-Kigoma regions		
Treatment	28 (28)	27(27)[c]
Control	154 (154)	151 (151)[c]
Kigoma region		
Treatment	0	2 (2)[d]
Control	0	11 (11)

Notes: The table excludes the 364 potential comparison communities not selected for the T&D and FS evaluations.

[a] At follow-up, two communities in the T&D comparison group merged with contiguous intervention communities, and one community in the Kigoma FS control group merged with another.

[b] With Kigoma not initially part of the T&D activity, we conducted no baseline surveys there; consequently, the region was excluded from the T&D evaluation.

[c] We dropped four intervention group communities from the T&D sample because they did not receive new lines before completion of the FS random assignment, one in the treatment group and three in the control group. They were not included in the follow-up survey.

[d] The 29 communities mentioned in the text about Figure III.1 include the 2 in Kigoma and the 27 outside Kigoma covered by the follow-up survey.

The community surveys were designed for community leaders though in some cases we allowed their representatives to respond. Even though the level of accuracy of responses by community leaders and their representatives likely varied by outcome, we have no reason to suspect that the accuracy varied systematically between intervention and comparison groups. Thus, imperfect reporting per se is unlikely to have resulted in biases in the estimated impacts on most community-level outcomes with one possible exception of community survey respondents' reporting on urban-rural status of their community. We suspect that some community survey respondents in rural areas at baseline may have incorrectly assumed that because they were getting new lines their community was going to be reclassified as urban (*mtaa*). More generally, based on discussions with the survey staff and a local consultant, we have the impression that there could be very reasonable misunderstandings about whether and when the official status of a community might change from rural to urban since there are a number of steps involved in making such changes and the decision to change could be reversed during this process

2. Follow-up household listing

During the period of administration of the follow-up community survey, the data collection team compiled full lists of all households in the targeted communities—at the subvillage level in rural areas and at the *mtaa* level in urban areas. The firm collecting the follow-up data (EDI) asked community representatives to review the baseline household lists and, for each household on the list, further asked community representatives to report whether the house was connected to the grid, whether it was located within 30 meters of a pole (if not already connected), and the household's current status (for example, whether the household was still in the community, had out-migrated, or was unknown to the community representative). Community representatives then listed all in-migrants and newly formed households in their communities. In each community, the data collection team visited a small number of randomly selected households to verify their information. If minor discrepancies were found between community representative reports and the data collection team's observations, these were recorded separately. For analysis purposes, we used the observations verified by the data collection team. If the team noted a substantial amount of incorrect information, it repeated the listing exercise. Although geographic boundaries had changed since baseline in some instances, the listing exercise followed the boundaries of the original/baseline community as much as possible. For all communities in Kigoma, no baseline lists existed, necessitating the creation of household lists from scratch, using the administrative community boundaries that existed in 2011.

We used the follow-up list data to assess the location status of the baseline sampled households, to identify new households in the study communities, and to assess whether households in the baseline sample were still residing in the community or had out-migrated. For households that were part of the baseline sample and had since out-migrated, the listing effort provided an opportunity to gather any relevant tracking information, such as households' new location or contact information (including mobile phone numbers). The list also recorded whether a household was newly formed or in-migrated to the community since the baseline survey (after October 2011), whether a household was connected to the electric grid, and whether it was located within 30 meters of an electric pole.

In Table IV.4, we summarize the baseline listing data for communities outside Kigoma as well as the follow-up listing data for Kigoma (where we had no baseline listing).[25] For the T&D group, even though the numbers of communities in the intervention and comparison groups were similar at baseline (Table IV.3), the intervention group included far more households (Table IV.4) despite our community-level matching. We suspect that, during the baseline community survey in 2011, some respondents reported on the size of the community as of the last census,

[25] In Chapter V, we analyze follow-up listing data outside Kigoma in the discussion on composition and mobility.

which, as noted, took place in 2002. Communities that grew rapidly since that time were more likely to receive new MCC lines. To help adjust for this reality, we included community size from the listing when performing household-level matching so that the household sample for the comparison group would come from similarly sized communities as the treatment group. As noted earlier, the number of FS treatment communities is much smaller than the number of FS control communities, and the same is true for households, as shown in Table IV.4. The difference in community size by FS status was small and not statistically significant.

3. Electric pole location data

During the period of administration for the follow-up community survey and household listing between May and July 2015, we also collected data on electric poles. We collected these data for a number of reasons. First, it was important to verify that poles were built. Second, we used these data to help verify which households were within 30 meters of a pole as we used that as a measure of “access” to the poles. Third, we had hoped to use these data to fix problems with GPS data collected at baseline. That effort did not prove successful, as explained in Appendix F, because the problems with the baseline GPS data turned out to be more extensive than we had realized. Fourth, we explored using the distance from the poles to the households as an IV when estimating impacts of being connected to the national grid (see Chapter VII). Finally, the pole data gave us a rough sense of how intense the intervention was in terms of poles per household.

While the pole data collected at follow-up are very helpful they have limitations—in particular, because we only collected data on poles that were within 40 meters of a household or other building or that could connect a household or building without an additional pole, we do not have data on all poles in each community. For this reason we do not present results on the ratio of poles to households as an outcome in our chapters on the impacts of the intervention. We do discuss such results here, with the caveat that they are only capturing a subset of the poles.

We gathered follow-up GPS data on the location of electric poles in the targeted communities— by subvillage in rural areas and by *mtaa* in urban areas. These data were only collected in communities that at the time had electric lines (170 intervention communities and 68 comparison communities). The exercise involved capturing GPS coordinates for every low-voltage pole in the community that was located within 40 meters of a house or building and any other poles that were connected to a house or building even if the poles were more than 40 meters away. For each pole, we also gathered the following information: when (month and year) the pole was energized and, for poles energized after October 2011 (about the time the baseline survey was conducted), whether a pole was an MCC-funded pole.

In Table IV.4, we also present data summarizing the pole data we collected as an indication of the degree of implementation of the T&D intervention. As the table shows, we collected data on the locations of almost 20,000 poles. The ratio of poles to households overall was about 0.30. In other words, there were roughly three households per pole in the sampled communities. In the final column of Table IV.4, we report on the ratio of poles to eligible households. As might be expected, the ratio is much larger in the intervention communities, at 0.35, compared to the comparison communities, at 0.18. At the same time, we find no clear differential in the ratio between the FS treatment and control communities outside Kigoma, which is what we would expect given that the FS treatment was randomly assigned.[26]

Table IV.4. Listing and pole data

	Households from listing data			Poles to eligible households
	Total	Eligible	Poles	
Total households	**91,077**	**67,007**	**19,946**	**0.30**
T&D evaluation (excludes Kigoma)				
Intervention group	53,106	36,639	12,989	0.35
Comparison group	31,861	24,258	4,359	0.18
FS evaluation				
Non-Kigoma regions				
Treatment	7,065	5,335	1,842	0.35
Control	46,041	31,304	11,147	0.36
Kigoma region				
Treatment	578	578	170	0.29
Control	5,532	5,532	2,428	0.44

Notes: Outside Kigoma, eligible households are those identified in the baseline listing data as not connected or not located within 30 meters of a pole. These households were the sampling frame for the baseline and follow-up surveys. We did not include Kigoma in the baseline data; therefore, the household listing data in this table come from the follow-up survey. We included Kigoma at follow-up only for the FS initiative evaluation. All households were eligible for the FS initiative; accordingly, all households in Kigoma were eligible for the follow-up survey. The pole data cover all poles in each community that were located within 40 meters of at least one household at the time of the follow-up survey. They include new poles built by MCC and poles built by other funders both before and after the baseline survey. For a total of 33 poles, it was unknown whether they were built by MCC or another funder.

Inside Kigoma, a large differential favors the control group communities. Communities in the control group in that region got about 50 percent more poles per household than those in the treatment group. This may partly reflect a small sample size issue—the fact that we had only two treatment communities in Kigoma. In addition, it implies that the FS initiative results in Kigoma do not provide a good estimate of the impacts of the FS initiative even after controlling for access to new lines. For this reason while we present Kigoma results in Appendix E, Table E.3f, we do not discuss them elsewhere in this report.

[26] We regressed the ratio of poles to eligible households on the T&D indicator, excluding the Kigoma communities and weighting by the number of eligible households. The T&D indicator was statistically significant. We ran a similar regression with the FS indicator, excluding both the Kigoma communities and the comparison communities. In this case, the FS indicator was not statistically significant, which suggests that randomization worked as anticipated. Finally, we ran a similar regression with the FS indicator, using only the Kigoma communities; again, the coefficient on the FS indicator was not statistically significant. The coefficient estimates change when we divide by all households instead of only by eligible households but the signs and statistical significance levels do not change.

We used the listing data in our analyses to measure total community size, in-migration rates, and new household formation rates. We aggregated the listing data up to the community level because we have little household-level information in the listing and thus cannot implement the matching procedures used for the household survey data when using the listing data.

4. Follow-up household survey

Data collection for the follow-up household survey started on August 31, 2015, and concluded on January 27, 2016.[27] In Table IV.5, we present the target sample size and response rates for the household sample for the T&D lines and FS initiative evaluations for the original six regions and Kigoma. The data collection team completed follow-up interviews with 8,899 baseline households (4,468 in the intervention group and 4,431 in the comparison group). The overall response rate from the follow-up household survey for the T&D evaluation was 81.6 percent, with only a 3 percentage point difference between the intervention and comparison groups. The response rate differential between the treatment and control groups for the FS initiative evaluation was less than 2 percentage points, with a response rate of 78.7 percent for the treatment group and 80.4 percent for the control group (numbers not shown in the table). The follow-up household survey response rate in Kigoma, where no baseline survey was administered, was 84.3 percent. In the map in Figure IV.1, we present the regional distribution of the intervention and comparison communities where we conducted the follow-up household survey.

After the baseline household survey was conducted, we discovered that some questions were not translated from English to Swahili correctly. The baseline report describes these issues in detail (Chaplin et al. 2012). In the process of writing this final report, we updated the English translation of the baseline household Swahili instrument. That updated translation will be made available as part of the public use data compiled by MCC for this project. In addition, all translation issues discovered in the baseline instrument were corrected in the follow-up instrument.

We constructed the final analysis file with follow-up household survey data after matching the comparison group households with the intervention group households. We used propensity score matching based on baseline household characteristics to find matched comparison group households. Two comparison households had propensity scores that fell outside the range of the propensity scores for the intervention households. We considered these households to lack common support and excluded them from our analyses Thus, our final post-matching analysis sample size for the T&D lines evaluation was 8,897 households from 178 intervention and 182 comparison communities (with 4,467 and 4,430 households, respectively).[28] The final analysis sample for the FS initiative evaluation without Kigoma included 4,467 households (632 in the treatment group and 3,385 in the control group). In Kigoma, we have another 444 observations with 29 in the treatment group and 415 in the control group.

[27] The follow-up household survey initially concluded on December 5, 2015, but it was extended for a three-week period from January 7 to 27, 2016, to improve the overall response rate for the T&D evaluation.

[28] We lose one additional observation due to missing values in control variables when we run regressions.

Table IV.5. Sample size and response rates in the follow-up household survey

Household sample	Total	Intervention group	Comparison group
Sample for the T&D and FS evaluations			
Non-Kigoma regions			
1. Targeted baseline sample	10,908	5,575	5,333
2. Total follow-up survey respondents	8,899	4,468	4,431
Interviewed at baseline and follow-up	*8,386*	*3,955*	*4,431*
Interviewed at follow-up only	*513*	*513*	*0*
3. Total response rate (2/1)	81.6%	80.1%	83.1%
Kigoma region[a]			
4. Sampled at follow-up	527	527	0
5. Total follow-up survey respondents	444	444	n.a.
6. Total response rate (5/4)	84.3%	84.3%	n.a.
New-household survey (all seven regions)			
7. Targeted sample	2,350	1,315	1,035
8. Total follow-up respondents	1,740	963	777
Confirmed in-migrant respondents	*529*	*293*	*236*
Confirmed newly formed household respondents	*299*	*127*	*172*
Respondent with unknown 2011 location status[b]	*896*	*533*	*363*
Other misclassified respondents [b, c]	*16*	*10*	*6*
9. Total response rate (8/7)	74%	73.2%	75.1%

Source: Tanzania energy sector follow-up household survey.

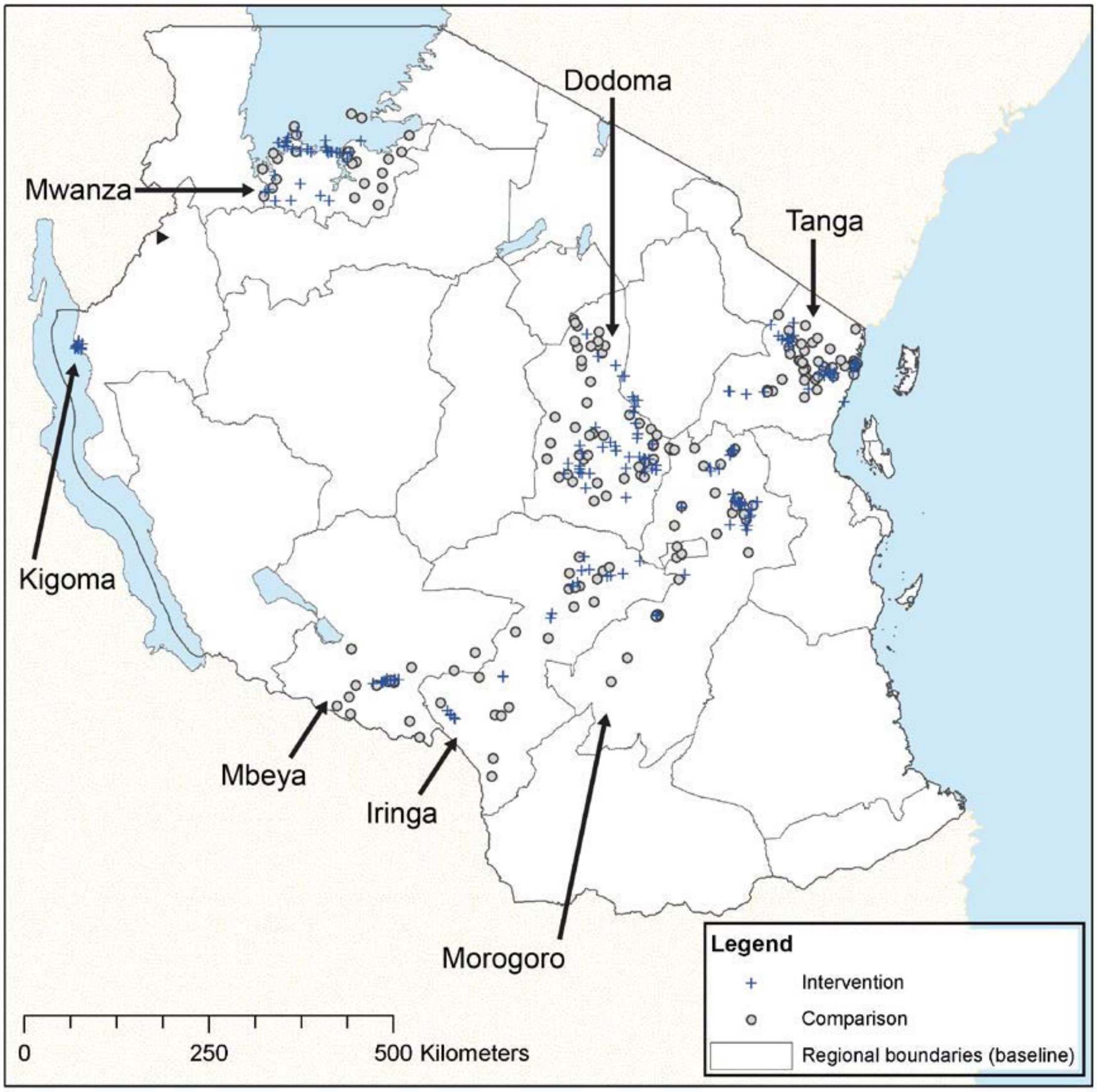
[a] The T&D evaluation excludes the Kigoma household sample. We include the Kigoma sample in the FS evaluation to assess whether estimated impacts in Kigoma differed from those in other regions. The Kigoma sample in this line excludes new households. Those households are included in the new-household samples in the lower part of this table.

[b] In the analysis of data for new households, we excluded households with unknown 2011 location status and other misclassified status. The listing classified most of them as new, but most of these households surveyed at follow-up indicated that they were present as households at the time of the baseline survey.

[c] "Other misclassified respondents" are households listed as in-migrants but indicating that they were newly formed (12) or vice versa (4).

n.a. = not applicable.

Figure IV.1. Locations of the intervention and comparison communities in Tanzania by region



Source: Tanzania energy sector follow-up household survey and Global Administrative Areas Database.

Notes: The figure shows the location of each community covered in our study, using the median latitude and longitude from GPS data collected at follow-up by EDI. This map covers 192 intervention communities (14 in Kigoma and 178 outside Kigoma) and 182 comparison communities. The regional boundaries date to 2011, the time of the baseline survey. Many of the boundaries have since shifted. Communities that appear to fall in water are located on islands in Lake Victoria that were not included in the regional boundary map.

5. New-household survey

Data collection for the new-household survey started on August 31, 2015, and concluded on December 5, 2015. In Table IV.5, we show the target sample size and response rates for the new-household sample. The data collection team completed interviews with 1,740 new households (963 in the intervention group and 777 in the comparison group) and achieved an overall response rate for the new-household survey of 74 percent, with less than a 2 percentage point difference between the intervention and comparison groups. Of the 1,740 new households interviewed, we found that only 828 households (529 in-migrant and 299 newly formed households) were confirmed to have been new to the community based on their response to the household survey questions; for the remaining 912 households, the information from the listing in each community and the households' own responses were contradictory regarding their location status in 2011. Given uncertainty about the location of the latter subset of new-household survey respondents, the sample size for our analysis of the new-household survey data totaled 828 households.

The sampling methods used for the new-household survey and nonresponse rates imply that, ideally, we should use weights to adjust for sampling and nonresponse. However, the large number of households that changed status suggests that the creation of such weights would pose significant difficulties. Consequently, we analyzed the data without weights and present the results as only suggestive.

C. Estimation approach

1. Estimating impacts of T&D lines

As noted in Chapter III, we used a matched comparison group evaluation design to estimate the impacts of the T&D lines. All matching was done without looking at the follow-up outcome data to ensure that no biases were introduced based on our preconceived notions regarding what the estimated impacts should be. We selected the matched communities in stages, as discussed earlier and in Appendix A. In a final matching stage, we constructed the T&D household comparison group by matching households in the communities not served by the T&D lines with those in the T&D communities (the intervention group). We use propensity score matching at the household level based on data from the baseline community and household surveys for those households in both groups of communities that responded to the follow-up survey. We used kernel matching to assign weights based on the estimated probability of membership in the intervention group. The matching weights resulted in a comparison group that was well matched to the intervention group. In addition, when we compared the two matched groups on a host of baseline characteristics not used in the propensity score model, we observed that the groups were statistically different for only a few characteristics. More specifically, households in the two groups were statistically different at the 5 percent significance level for only 14 of 192 characteristics and at the 10 percent significance level for only 22 characteristics (see Appendix B for details).[29] At each statistical significance level, the incidence of such differences was not statistically distinguishable from what might occur by chance alone. In other words, the matching weights succeeded in making the comparison group households statistically equivalent to the intervention group on a range of observed characteristics. For more details on our matching methods, see Appendix A.

[29] This low level of statistically significant differences may happen in part because all of the baseline variables not used in the final propensity score matching model were considered for that model. More precisely, we used an iterative process to choose our final propensity score model. After each iteration we checked to see which variables differed in a statistically significant way between the intervention group and the matched comparison group created in that iteration. Such variables were included in the next iteration of the model if they were considered substantively important.

We estimated impacts of the T&D lines by using a regression-adjustment approach that allowed us to account further for any differences in observed baseline characteristics between the matched comparison and intervention groups, particularly those characteristics that appear to be statistically significantly different post-matching. In addition, the regression-adjusted approach may increase the precision of the impact estimates. We estimated impacts of the T&D lines on household outcomes by using a regression model of the following form:

$$(1) \quad Y_{hct} = \alpha + \beta_1 I_c + X_{hc,t-1}\gamma + S_{c,t-1}\delta + \varepsilon_{hct}$$

where, Y_{hct} is the outcome of interest for household *h* in community *c* at time *t* (with *t* denoting the follow-up, *t-1* denoting baseline); I_c is a binary indicator of the intervention status of community *c* (equals one for a community targeted to receive new lines under the T&D lines) and β_1 represents the estimated impact of the T&D lines; $X_{hc,t-1}$ is a vector of baseline household characteristics, including a baseline measure of the outcome ($Y_{hc,t-1}$) or a close proxy, when available, and any baseline characteristics for which post-matching differences between intervention and comparison groups remain statistically significant at the 5 percent level; and $S_{c,t-1}$ is a vector of baseline community characteristics. Table C.3 in Appendix C lists the outcomes that had no lagged outcome and a proxy for the lagged outcome of one variable.

We estimated impacts of T& lines on community-level outcomes by using a regression model similar to equation (1), except that we used only community-level control variables. Thus, the regression model is of the following form, and β_2 represents the estimated impact of the T&D lines:

$$(2) \quad Y_{ct} = \alpha + \beta_2 I_c + S_{c,t-1}\delta + \varepsilon_{ct}$$

In Table IV.6, we present the baseline characteristics used as control variables in the regression models for estimating impacts of the T&D lines.[30] As shown in the first few lines, the community-level variables differed depending on the data being analyzed—household survey, community survey, or listing data (when analyzed at the community level). We used variables describing the sub-village/*mtaa* when analyzing the household survey data and variables describing the village/*mtaa* when analyzing the community survey and listing data. Similarly, the household-level variables differed depending on whether we were doing the T&D lines or FS initiative analyses.

[30] We controlled for a large number of variables in our regression models, which may be cause for concern regarding degrees of freedom. However, for household analyses, we have over 8,000 observations and comparatively few control variables (31). At the community level, we only estimate T&D impacts, which gives us a sample size of 360 observations, and only 21 control variables.

Table IV.6. Baseline characteristics used as control variables for T&D lines and FS initiative impact analyses

Type	Baseline characteristics
Community-level variables used as controls by data source for outcomes	
Household survey outcomes: Subvillage/*mtaa* characteristics	Urban-rural status; community size (total number of households for the sub-village/*mtaa* from the listing); whether community is connected to the grid; percent of household in the community connected to the grid; number of households not connected or within 30 meter of existing line; average household income
Community survey and listing data outcomes: Village/*mtaa* characteristics	Urban-rural status; has sub-village at baseline; region; number of households in community reported by the community survey respondent; has police station, post office, or bank; number of households in community surveyed in listing data; distance to nearest regional capital; community has weekly market; community accessible by paved road; community connected to national or isolated grid; percentage of community connected to grid; natural log of the price of land in the community; community has a secondary school; community has dispensary; community had a public water supply project in the past two years
Household-level variables used as controls when analyzing household survey outcomes	
For all analyses: Household demographics	Gender, age, education level, and marital status of the household head; number of household members; household income per capita per day; total household energy use
For T&D impact analysis: baseline characteristics with post-matching statistically significant differenced at 5% level	Amount of candles used by households per month; household expenditure on grid electricity; amount of grid electricity used; whether any adult household member (15 and older) missed work in the last 30 days due to illness; whether any male adult household member (15 and older) missed work in the last 30 days due to illness; whether any female adult household member (15 and older) missed work in the last 30 days due to illness; whether household uses well or borehole as their water source whether household uses water sources other than piped or ground water, rain, kiosk, vendor, and water truck; number of rooms in the dwelling; whether household has spoken to a ward development officer about a program to inform people about the benefits of electricity; number of income generating activities owned by household; number of female-owned income-generating activities; average length of time household is operating income-generating activities; time spent by adult females on other activities; time spent by female adults on shopping
For FS impact analysis: baseline characteristics with statistically significant treatment-control differenced at 5% level	Household expenditure on grid electricity; household expenditure on satellite dish and cable TV; whether household has a landline phone; amount of water pumped by household; whether any male adult household member (15 and older) missed work in the last 30 days due to illness; time spent by adult females sleeping at night; time spent by adult females socializing; number of female-owned income-generating activities; number of income-generating activities using non-electric energy

We estimated equations (1) and (2) by using ordinary least squares regression models for continuous and binary outcome measures and using multinomial logit models for categorical outcomes. We estimated impacts for all households in the analytic sample, without any exclusions. For impacts on community-level outcomes, the standard errors of the estimated impacts account for clustering at the district level by using the Huber-White "sandwich" estimator of variance; for impacts on household-level outcomes, the standard errors of impacts account for clustering at the community (that is, subvillage or *mtaa*) level. [31] We used Stata's

[31] Our standard errors do not account for the fact that our propensity scores were estimated. Doing so would have been very complex given the multiple levels of matching.

margins command to generate the estimated impacts and means for the intervention group presented in this report.[32]

In addition to estimating impacts of the T&D lines on outcomes for all households, we were interested in estimating whether the T&D lines produced different impacts on different types of households. We defined five sets of subgroups by the following baseline household characteristics: gender of the household head; whether the household head was younger than age 25 or age 25 and older; gender of the household head when the current head was younger than age 25; quartiles of household income; and whether the household lived in an urban or rural community. To be responsive to the multiple comparisons problem, we estimated subgroup impacts only on primary outcome measures and restricted the number of subgroups examined.

To estimate the subgroup impacts, we modified the regression model shown in equation (1) to include the interaction of the intervention status indicator with indicators for each subgroup set (with one subgroup omitted). We dropped observations missing the relevant subgroup variable and conducted statistical tests to determine the statistical significance levels of the impacts of T&D lines on each subgroup, along with a statistical test to assess whether the estimated subgroup impacts differed from each other.

2. Estimating impacts of FS initiative

Even though well-executed random assignment ensures that a simple comparison of mean values of outcomes for the treatment and control groups yields unbiased estimates of program impacts, we used the regression-adjustment approach for estimating the impacts of the FS initiative in order to increase precision of the impact estimates and to control for any differences in baseline characteristics between the treatment and control groups. When we compared the treatment and control group households on a host of baseline characteristics, we found that they were not statistically different for most characteristics. Households in the two groups were statistically different at the 5 percent significance level for 9 of the 191 characteristics and at the 10 percent significance level for 19 characteristics (full results in Appendix B).

We estimated impacts of the FS initiative by using the regression model shown in equation (3), which is similar to equation (1) except that the intervention indicator (I_c) is replaced with a treatment indicator (T_c):

$$(3) \quad Y_{hct} = \alpha + \beta_3 T_c + X_{hc,t-1}\gamma + S_{c,t-1}\delta + \varepsilon_{hct}$$

where the notation is similar to equation (1), and β_3 represents the estimated impact of the FS initiative. In Table IV.6, we show the baseline characteristics used as control variables in the regression model for estimating impacts of the FS initiative.

We estimated equation (3) by using the same approach applied for estimating equation (1): ordinary least squares regression for continuous and binary outcome measures and multinomial

[32] The impacts are generated as average marginal effects of being in the intervention group.

logit models for categorical outcomes. We included all treatment group households in the analytic sample, regardless of whether they accepted the FS offer of a low-cost connection.[33] The standard errors of estimated impacts account for clustering at the community (that is, subvillage or *mtaa*) level. Again, we used Stata's *margins* command to generate the estimated impacts and means for the treatment group presented in this report. We also estimated FS impacts for the same set of subgroups as discussed above for the T&D lines impact analysis, using a similar estimation approach with interaction of the treatment status with an indicator for a specific subgroup.

We did not estimate impacts of the FS initiative on outcomes measured in the community survey because the FS initiative was implemented in only one subvillage in each village covered by the community survey. In contrast, T&D lines were installed across many subvillages in each village.

3. Exploratory impacts of connecting to the grid

For the exploratory analysis of the impacts of connection to grid electricity on household outcomes, we started with our full T&D evaluation sample including both intervention and comparison group households. This was helpful because a large fraction of the comparison group did get connected. We then used propensity score matching to produce matching weights in order to match unconnected households to connected households as a group. As with the T&D analysis, all matching for the exploratory analysis of impacts of actually connecting was done without looking at the follow-up outcome data (except for connection status) to ensure that the results were not influenced by our pre-conceived ideas about what the estimated impacts would be. Households were matched based on a rich set of household and community characteristics (see Appendix A for details). The matching weights differed from the ones we used for the T&D impact analysis. They ensure that the unconnected households are well matched to the connected ones. When we used these weights and compared the connected and unconnected households on a host of baseline characteristics not included in the propensity score model, we observed that they were statistically different for only a few characteristics. More specifically, households in the two groups were statistically different at the 5 percent significance level for only 10 of the 192 characteristics and at the 10 percent significance level for only 13 characteristics (full results in Appendix B). At each statistical significance level, the incidence of such differences was not statistically distinguishable from what might have occurred by chance alone. In other words, the matching weights made the unconnected households statistically equivalent to the connected households on a range of observed characteristics.

As with the T&D impact analysis, we used regression adjustment to estimate the impacts of connection to the grid on household outcomes. In Table IV.7, we show the baseline characteristics used as control variables in the regression model for estimating impacts of connection to the grid. Unlike the T&D impact analysis, the control variables for the exploratory analysis include baseline measures of whether the community was accessible by a paved road

[33] In the FS impact analysis, we also assessed whether impacts in Kigoma were similar to those found outside Kigoma for the primary outcomes in each domain. Because we do not have baseline data on characteristics of households in Kigoma, we did not control for any baseline characteristics when estimating FS impacts in Kigoma. We conducted a statistical test of whether the estimated impacts for Kigoma differed from those outside of Kigoma. See Appendix E, Table E.3f for these results.

and whether it had had a public water supply project in the last two years. The T&D impact analysis was designed to capture all impacts of building new lines, including impacts via increased investments in other infrastructures. Had we found evidence of impacts on those, we would have controlled for their follow-up values in the exploratory analysis. Since we did not find such evidence, we controlled only for the baseline values.

Table IV.7. Control variables for the exploratory analysis of impacts of being connected to the national grid

Type	Baseline characteristics
Household demographics at baseline	Gender, age, education level, and marital status of the household head; number of household members; household income per capita per day; total household energy use
Community characteristics at baseline	Urban-rural status; community size (total number of households); whether community is connected to grid; percentage of households in community connected to grid; number of households not connected to or within 30 meters of existing line; average household income; community has weekly market at baseline; community accessible by paved road at baseline; community had a public water supply project in the past two years
Baseline characteristics with statistically significant difference post-matching	Age of household head; household head is 18-24 years of age; any adult 15 or older missed work in last 30 days due to illness; household received HIV info from TV/radio/internet/phone in last 30 days; fuel costs – kerosene; nonwage income; wall is electrifiable; fraction who have spoken to a ward development officer; household has a female 15 years or older who was unable to work due to illness; average year income-generating activity established

4. Other analytic considerations

Survey nonresponse and sampling weights for the T&D intervention group. As noted earlier, we oversampled households in the intervention group that were eligible for a potential targeted subsidy-pilot intervention (which, ultimately did not materialize). We approximated eligibility based on whether the household appeared to have a dwelling with two or fewer rooms using the baseline household listing data. We then oversampled those households so that 40 percent of the resulting sample qualified for the subsidy-pilot intervention versus 25 percent in the sampling frame. We created sampling weights to account for the oversampling so that our estimates would represent the full population of households in the intervention group. We did not oversample any subset of households in the sampling frame for the comparison group and therefore do not have a sampling weight for the comparison group.

We then adjusted the sampling weights to account for follow-up survey nonresponse. The follow-up survey response rates for the evaluation samples were remarkably high. Even with relatively high response rates, if respondents differ systematically from nonrespondents and we do not account for the differences, the estimated impacts may be biased and thus not represent all households in the study communities. To account for potential differences between the respondent and nonrespondent samples, we adjusted the sampling weights for the intervention group for survey nonresponse. In Appendix A, we provide a description of the calculation of survey weights. Because we used kernel weights from propensity score matching to make households in the comparison group similar to those in the intervention group, we did not explicitly create separate weights to account for survey nonresponse among the comparison group households.

Weights used in impact analysis at the community-level. We weighted the community-level impact analysis by community size (number of households reported in the community survey) so that the results describe conditions for households on average in those communities. Such weighting makes the results more comparable with our household survey than they would be if they were not weighted. However, for a number of reasons, the households covered by our household and community surveys differ. First, in rural areas, the household survey covered only one subvillage within the village that was surveyed. We selected the subvillages based on the fraction of households expected to have access to electricity after construction of the new lines.[34] Rural households represent about 70 percent of our household sample. Second, in the household survey we excluded households that were connected or within 30 meters of a line at baseline. Third, in all areas, we sampled about 16 percent of households (on average), which would affect the precision of the estimated impacts. It is not clear how these differences in sampling affected our results. On the one hand, the community survey presents results for a far larger number of households, perhaps suggesting that our estimated impacts at the community level are more precise. On the other hand, the community survey covers households already connected at baseline and all subvillages in each village, perhaps including subvillages less likely to benefit from the new T&D lines than the subvillages in the household survey—hence, we might expect smaller impacts on comparable outcomes in the community survey than in the household survey.

Missing data. For most of the control variables in our regression models, only a few observations had missing data; we replaced the missing data with the community-specific mean values of those variables calculated from the non-missing observations. For any control variables for which the value was missing, we included a dummy variable in our regression model to indicate a missing value. For outcome measures, we excluded from the analysis any observations with missing data.

Small subgroup sample sizes. When performing subgroup analyses, we omitted analyses resulting in subgroup sample sizes below 30. We observed such sample sizes when we tried to estimate impacts by age (< or > = 25) and gender simultaneously.

Comparing estimated impacts of T&D lines, FS low-cost-connection offers, and being connected. In general we would not expect the estimated impacts of T&D lines, the FS initiative, and being connected to align. For some outcomes, the estimated impacts of T&D lines and the FS initiative are likely to be much smaller than the estimated impacts of being connected to the grid. This is especially likely for outcomes that are affected directly by being connected, such as use of electric lights in the home, and hours children spent on studying at night. For such outcomes, the analysis may not have sufficient statistical power to detect the relatively small impacts of T&D lines and the FS initiative. For other outcomes that capture spillovers from living in communities with households that have electricity, impacts may be similar for T&D lines and the FS initiative versus being connected. For example, the light from households with electricity in a community may make all people in that community feel safer when walking at night, regardless of whether or not they are connected themselves. Thus we may observe impacts

[34] We selected subvillages in this manner to increase the likelihood that the survey would capture households that gained access to the new lines.

of T&D lines and the FS initiative on this outcome that are similar to the impacts of being connected on this outcome.

Sensitivity to estimation approach and model specification for regression adjustment. We tested the sensitivity of our impact estimates to using alternative estimation approaches and alternative model specifications for regression adjustment, and found that these alternative analytic choices made little substantive difference. The findings we present in this report rely on a linear regression approach and include observations with missing data in some control variables by replacing the missing values with community-specific mean values from complete cases. For all impact analyses, we also estimated the following alternative models: logistic regression for binary variables, and linear regressions with observations with missing data on control variables excluded from the analyses; for the FS initiative analyses, we also estimated impacts without regression adjustment since our FS initiative impact estimates are based on a random assignment design and do not need regression adjustment to produce unbiased estimates. The results from these various analyses are qualitatively very similar to what we present in the report. We identified the number of outcomes for which the impact estimates changed in significance and estimated the Pearson correlation coefficient between the impact estimates in the main model and the alternative models (Table IV.8). The correlation between the impact estimates in the main and alternative models are near perfect with all of the correlation coefficients close to 1. In terms of variation in statistically significant impact estimates, even when statistical significance levels of estimated impacts change, the magnitudes of the estimated impacts remain very similar across model specifications. Only two outcomes changed significance levels in the T&D lines analysis and neither affect our findings in a substantive way. In the FS initiative analysis, nine outcomes were no longer significant in the alternative models and six were significant in the alternative model but not in the main model; these 15 outcomes were less than 10 percent of the 173 included in the alternative models. None of the estimated impacts of the FS initiative that are not significant at the 0.05 level in our preferred specification (linear adjusted) are significant in the alternative models. Four estimates differ in the other direction. Those differences and changes at the 0.10 level are discussed in Chapter VI.

Table IV.8. Summary of sensitivity analyses using alternative estimation approaches

	T&D evaluation	FS evaluation
Number of outcomes analyzed		
Main model[a]	103	101
Alternative models[b]	76	173
Pearson correlation coefficient of the impact estimates of the main model and alternative models		
Linear regression excluding cases with missing data in control variables	0.9998	1.0000
Logistic regression	0.9996	0.9981
Estimation without regression adjustment	N/A	0.9999
Number of impact estimates where the significance level differs between the main and alternative models		
Lower significance in the alternative model	1	13
No longer significant in the alternative model	0	9
Higher significance in the alternative model	1	2
Significant in the alternative model but not in the main model	0	6
Total number of differences between models	2	30

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

[a] The main model for all analyses uses a linear regression approach and included observations with missing data in some control variables (by replacing the missing value with community-specific mean value from complete cases).

[b] The alternative models include Linear regression excluding cases with missing data in control variables, Logistic regression, and, for FS only, estimation without regression adjustment.

This page has been left blank for double-sided copying.

CHAPTER V

IMPACTS OF T&D LINE EXTENSIONS

This page has been left blank for double-sided copying.

Executive summary

Under the T&D activity, MCC invested $124 million to build 2,595 kilometers of new medium- and low-voltage distribution lines and rehabilitate the existing electricity transmission and distribution infrastructure in 7 of the country's 26 regions. The new lines were expected to affect outcomes across multiple domains: connection rates, energy use, education and child time use, health and safety, business and adult time use, and economic well-being and composition and mobility.

Key findings from the T&D line extensions evaluation:

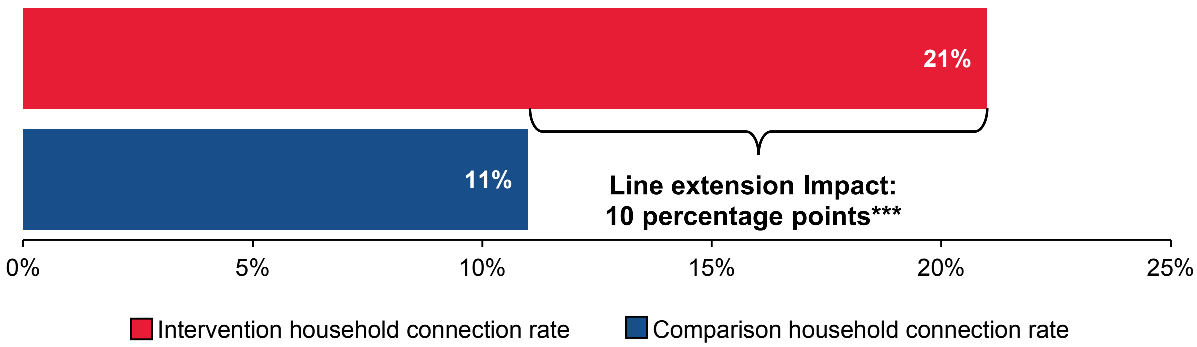
- The line extensions led to a large number of new connections; however, it was less than a third of the 35,000 connections assumed at the outset.
- The line extensions increased consumption of grid electricity, ownership of electric tools, time spent watching television, and perceived safety.
- The line extensions increased the percentage of communities with an electrified school.
- The line extensions increased the percentage of communities with an electrified business and the percentage of households operating an income generating activity (IGA) that uses grid electricity.

To assess the impacts of the line extensions component of the T&D activity, we used a nonexperimental comparison-group design, where we estimated the impacts of the activity by comparing outcomes for the households and businesses living in the line extensions communities with a matched group of comparison communities. As such, our evaluation examines the direct impacts of line extensions in the beneficiary communities. This also incorporates impacts of the low-cost connection offers that were made in 27 of the 178 communities that were targeted to receive the new lines. We used community survey data covering 358 communities and household survey data from over 8,900 households. The community-level data cover outcomes that do not vary across households, such as access to electrified facilities, roads, and water. The household-level data include information that community representatives may not be able to provide with full accuracy, such as average household income, perceived safety, and health.

Connection rates

A key outcome of interest was connection rates and although there were many new connections, there were fewer than expected. The line extension increased connection rates by 10 percentage points from 11 percent to 21 percent (Figure ES.V.1). The economic rate of return analysis prepared by the MCC before the implementation of the energy project assumed that 35,000 new connections will be installed within a year following the construction of the lines; we estimated that there were 10,794 connections—about 31 percent of the original projection—two to three years after the lines were constructed.

Figure ES.V.1. Impacts of line extensions on connection rates



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

Notes: The line extension analysis sample includes 8,897 households, with 4,467 in the intervention group and 4,430 in the comparison group. Impacts presented are regression-adjusted.

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

Households connected to the grid in the intervention group reported having grid electricity for about 15.7 hours per day and experiencing 1.7 power surges per week, on average. The estimates reflect some of the supply-side constraints in the Tanzanian electricity sector, including those related to power-generating capacity and reliability of the electricity supply infrastructure.

Energy use

The line extensions had no clear impact on the overall amount of energy used by households, but it increased grid electricity use while reducing use of electricity from nongrid sources, such as generators. This substitution of grid electricity for nongrid electricity 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. Indeed, the line extensions increased the use of electric tools and appliances and amount of light consumed. It also increased the share of households who now charge mobile phones at home and thereby reduced mobile phone recharge expenses by about 22 percent. However, we did not find any clear impacts on kerosene or solid fuel use, which is not surprising given liquid fuel such as kerosene is already being replaced by dry cell batteries in nonelectrified households in most African countries.

Impact of T&D line extensions by gender, age, and income of household.

- Impacts on connection rates were higher for male-headed households and those with a head age 25 years or older.
- Line extensions increased connection rates in each income quartile, but the impacts increased monotonically from the lowest to the highest quartile.

Education and child time use

The line extensions had a positive impact on the fraction of communities with electrified schools with over half of communities that received the new lines having an electrified school compared to about one third of the comparison communities. The line extensions did not clearly increase the amount of time children spent studying at night but did boost the amount of time children spent watching television by about seven minutes per day.

Health and safety

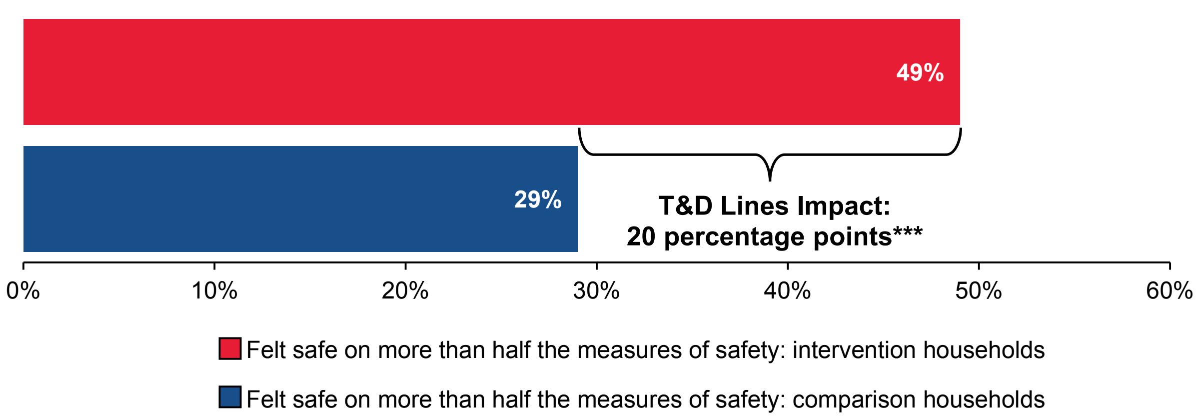
While line extensions increased access to electrified schools, it had no clear impact on access to electrified health facilities. It also had no clear impacts on health problems. Improvements in health might have been found if the line extensions had reduced the use of kerosene and solid fuel for lamps and cooking and thereby reduced pollution. However, we found no clear impacts on those outcomes.

The line extensions improved perceived safety at night. We asked households if they thought communal light was sufficient, if they felt safe walking at night, if they felt that the community lights helped reduce crime, and if they felt that the community lights helped keep them safe from animals at night. We found that the line extensions increased perceived safety by 20 percentage points with just under half of respondents reporting feeling safe on more than half the measures (Figure ES.V.2). Based on the community survey data, the line extensions increased by 22 percentage points the share of households in communities with outside light available on a cloudy night.

Business and adult time use

About 96 percent of communities that received the new lines had an electrified business—an impact of 44 percentage points. The line extensions increased the percentage of households operating an IGA that used grid electricity from seven to nine percent. However, there were limited impacts on economic activities and adult time use; it increased the time both men and women spent collecting water and fuel and watching television.

Figure ES.V.2. Impacts of line extensions on perceived safety at night



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

Notes: The line extension sample includes 8,897 households, with 4,467 in the intervention group and 4,430 in the comparison group. Impacts presented are regression-adjusted.

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

Economic well-being and composition and mobility

We hypothesized that the line extensions may increase land value and affect migration because the new lines would make the community more attractive, but we found mixed results. The line extensions increased the price of residential land by about 34 percent, based on community survey respondent reports. But we did not find any statistically significant impacts on migration. There were also no clear impacts on other measures of economic well-being, such as annual income or the fraction of households consuming less than $1 or $2 USD per day.

Introduction

In this chapter, we present the main findings from the impact analysis of the line extension component of the T&D activity. The T&D activity included the building of 2,595 km of new medium- and low-voltage electricity lines[35] across several regions of Tanzania and was expected to affect outcomes in seven domains: (1) connection rates; (2) energy use; (3) education and child time use; (4) health and safety; (5) business and adult time use; (6) economic well-being; and (7) community composition and household mobility. The impact evaluation design for the T&D lines is a nonexperimental design with a matched comparison group. We present estimated impacts on community and household outcomes for the overall sample as well as for key subgroups.

The community- and household-level data complement each other in two ways. First, they provide information on different types of outcomes. The community-level data cover outcomes that do not vary across households, such as access to electrified facilities, roads, and water. The household-level data include information that community respondents may not be able to provide with full accuracy, such as average household income, perceived safety, and health. Second, the community-level data cover a larger population than the household survey, albeit a population for which impacts are expected to be somewhat smaller.[36] We also have data on a few outcomes in the connection domain from the household listing, which covers the same population as the household survey but with far greater precision.[37] To make the community-level results apply to the households in the communities of interest, we weighted the community-level impact analysis by baseline community size (number of households reported by the community survey respondent).

We organize our discussion by domain and, within each domain, first describe findings for primary outcomes measured at the community and household levels and then discuss secondary outcomes. Detailed definitions of these outcomes are presented in Appendix C.

---

[35] There were 1,277 medium-voltage lines, which are those constructed up to the transformer (before consumers can be connected) and are 33/11 kV lines. There were 1,318 low-voltage lines, which are the lines constructed from the transformers ready for consumer connections and are typically up to 0.4 kV lines in Tanzania.

[36] The population covered by the community survey is larger than that covered by the household survey. In rural areas, where about 70 percent of the households in our sample reside, the community data cover entire villages, whereas the household data cover only one subvillage within each of the villages covered by the community survey; that subvillage is expected to end up with the highest fraction of households connecting to the grid.

[37] The community-level variable that is based on the listing data in the connections domain covers the same communities as the household survey (subvillages in rural areas) but includes all eligible households; the household survey data cover only a 16 percent sample. The listing data also cover noneligible households (those connected to or located within 30 meters of a line at baseline), but this variable does not cover those households.

A. Main findings

1. Connection rates

The T&D lines had positive impacts on connection rates and access to grid electricity based on both community- and household-level measures (Tables V.1 and V.2), though lower than had been projected by MCC.

The T&D lines had substantial positive impacts on the primary outcomes in the domain of connection rates—fractions of households connected to the national grid measured at the community and household levels. Based on the community survey reports, the T&D lines had a 6 percentage point impact on the fraction of households connected to the grid (an increase of 43 percent relative to the comparison group mean of 14 percent).

For at least two reasons, we expected the impacts on connection rates to be higher at the household level than at the community level. First, almost none of the households covered in the baseline household survey was connected at baseline, whereas many of those covered in the community survey were connected. Second, the household survey targeted the subvillage with the largest expected impact on connection rates within each village covered by the community survey. The results (Table V.1) support our expectation.[38]

MCC was not the only funder of new lines in our study communities, but it appears that the T&D lines did not affect the placement of other lines. In particular, of the over 4,000 poles identified in the comparison communities, only 400 were funded by MCC. In contrast, out of the almost 13,000 poles in the intervention communities, about 5,000 were funded by MCC.[39] Drawing on pole location data, we found that the T&D lines increased the fraction of households connected to the new MCC-funded lines by 9 percentage points and had no clear impact on the fraction connected to non-MCC lines (those built either before or after 2011). We observed little crossover from the comparison group to the intervention group, with only about 1 percent of comparison households connected to the MCC-funded lines.[40]

[38] A secondary measure using data from the follow-up household listing shows that the activity increased the fraction of households connected by 16 percentage points (a relative increase of over 200 percent). For the same outcome measured with data from the follow-up household survey, the estimated impact is 10 percentage points (a relative increase of 91 percent). The difference in results between the household listing and the household survey suggests that the community leaders who provided the listing data may have overestimated connection rates. In addition, we based the household survey results on regressions at the household level but analyzed the household listing data at the community level and with a different set of control variables (discussed in Chapter IV). This may have also affected the results.

[39] These numbers exclude Kigoma and cover poles only within 40 meters of at least one house.

[40] A few comparison communities were slated for access to MCC-funded lines per decisions made during the implementation stage of the T&D activity, long after we identified the matched comparison communities. In addition, in other cases, MCC-funded lines passed near or through the edges of communities not intended for access to lines; therefore, a few households may have gained access incidentally.

Not all intervention communities ultimately received MCC lines. However, if we consider both MCC and non-MCC lines, about 98 percent of households in the intervention group were in communities with electric lines at the time of the follow-up survey, for a rate 45 percentage points higher than the comparison group rate of 53 percent (Table V.1).[41] At the same time, the T&D lines had no statistically significant impact on the share of households in communities with access to sources of electricity other than the TANESCO grid, namely, isolated grids, generators, solar power, windmills, or other sources.

Based on the household-level impacts of the T&D lines, we estimate that MCC achieved about 31 percent of the targeted number of connections assumed in an economic rate of return (ERR) calculation MCC produced in 2008. The ERR was based on an estimate of 35,000 new connections in the year after the lines were built. In comparison, we estimate that there were a total of 10,794 new connections to MCC lines by the time of the follow-up survey. We explain in Appendix I how we obtained this estimate.

We found that the T&D lines had a much greater positive impact on access, as measured by proximity to the electric pole, than on connection rates. This is part of the reason that, as noted above, it did not translate into as high an impact on connection rates as was projected by MCC. More precisely, we found consistent evidence that the T&D lines had statistically significant positive impacts on access to electricity when we measured impacts with data from the follow-up household survey, GPS records, and the household listing; the estimated impacts range between 19 and 29 percentage points (relative increases between 62 and 138 percent), depending on the measure (Table V.2). With improved access to electricity, the activity also increased the average period of time for which households were connected to the grid by about one-quarter of a year (a relative increase of 111 percent).[42]

[41] In 2011 at the time of the baseline survey, about 37 percent of the comparison communities had access to electricity lines, and about 42 percent of the intervention communities had electricity lines that passed through some part of the community.

[42] The intervention group households connected to the grid had been connected for about 2.3 years, on average (estimate not shown in table). That duration appears relatively high given that the follow-up household survey was conducted between 1.7 and 2.8 years after construction and energization of MCC-funded lines. However, the estimate includes households connected to non-MCC lines built before December 2013, which is when the first MCC lines were energized.

Table V.1. Community-level T&D impacts on connection rates

Follow-up outcome	Comparison mean	Impact	Standard Error	*p*-value
Primary outcomes				
Fraction of households connected to national grid (based on community survey data)	0.14	0.06	0.02***	0.01
Secondary outcomes				
Fraction of households (based on follow-up household listing)[a]				
Connected to national grid	0.07	0.16	0.04***	0.00
Within 30 meters of grid	0.11	0.30	0.07***	0.00
Community (based on the community survey) has access to				
National grid	0.53	0.45	0.05***	0.00
Isolated grid	0.03	0.04	0.03	0.20
Generator	0.64	-0.12	0.09	0.18
Solar, windmill, and other electricity sources	0.98	0.02	0.03	0.53

Source: Tanzania energy sector baseline and follow-up community surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for community-level explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 358 communities, with 178 in the intervention group and 180 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using community size (number of households) as weights to make the community-level results apply to the households in those communities.

[a.] This outcome captures only the set of sub-villages covered by the household survey and only households that were in the community and not connected or within 30 meters of a pole at baseline. The remaining variables in this table cover all households in all sub-villages covered by the community survey.

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

Table V.2. Household-level T&D impacts on connection rates

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Primary outcomes				
Household is connected to national grid	0.11	0.10	0.02***	0.00
Secondary outcomes				
Household is connected to				
MCC lines	0.01	0.10	0.01***	0.00
Non-MCC lines built after 2011	0.06	0.02	0.01	0.14
Non-MCC lines built before 2011	0.04	-0.01	0.01	0.45
Household has access to grid without additional poles[a]	0.32	0.19	0.03***	0.00
Household is within				
30 meters of nearest electric pole (GPS data)	0.14	0.19	0.02***	0.00
30 meters of nearest electric pole (household listing data)	0.22	0.25	0.03***	0.00
30 meters of nearest electric pole (household survey data)	0.24	0.20	0.03***	0.00
40 meters of nearest electric pole (GPS data)	0.20	0.22	0.03***	0.00
40 meters of nearest electric pole (household survey data)	0.28	0.23	0.03***	0.00
50 meters of nearest electric pole (GPS data)	0.24	0.25	0.04***	0.00
50 meters of nearest electric pole (household survey data)	0.32	0.25	0.03***	0.00
100 meters of nearest electric pole (GPS data)	0.32	0.29	0.04***	0.00

Table V.2. *(continued)*

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
100 meters of nearest electric pole (household survey data)	0.44	0.27	0.03***	0.00
Average years household has been connected to national grid[b]	0.23	0.25	0.04***	0.00
Average hours per day household has grid electricity[b]	1.63	1.67	0.29***	0.00

Source: Tanzania energy sector baseline and follow-up household surveys, follow-up listing of households, and follow-up GPS location data.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 4,467 in the intervention group and 4,430 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

[a] TANESCO requires additional pole(s) for connecting to the grid if a house was located more than approximately 30 meters away. Because it is very costly to install additional pole(s), households who can connect to the national grid without additional pole(s) have better access to electricity. This outcome is based on responses from a household survey question, "Are you able to connect to the nearest electrical pole without purchasing any additional poles?".

[b] The average includes households that were not connected to the national grid.

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

Consistent with the positive impact on the fraction of households connected to the national grid, we found a positive impact on the number of hours per day that households have grid electricity. The line extensions increased by about 1.7 hours the time households had grid electricity each day, more than doubling the hours relative to comparison communities; the estimate is statistically significant at the 1 percent level.[43]

We also measured the quality of electricity (not reported in Table V.2). Households connected to the grid in the intervention group reported having grid electricity for about 15.67 hours per day and experiencing 1.71 power surges per week, on average. The estimates reflect some of the supply-side constraints in the Tanzanian electricity sector, including those related to power-generating capacity and reliability of the electricity supply infrastructure.[44] Indeed, the fact that connections were so much lower than expected may also be due in part to supply-side constraints, as discussed in our qualitative report (Miller et al, 2015). For example, it appears that

[43] Note that we calculate the average number of hours household had grid electricity for all households in the sample, connected and not connected. Thus, the increase in the number of hours per day households had grid electricity is likely to be the result of the line extensions communities having more connected households rather than changes in the reliability of grid electricity.

[44] We also estimated the difference in power surges of connection to an MCC line versus a non-MCC line and found no statistically significant difference, though the point estimate was negative (-0.15). The regressions used the same regressors and weights as our other household-level impact analysis but excluded nonconnected households. As discussed in Chapter IV, we are concerned that MCC line status may be overestimated in FS treatment communities. When we exclude those communities, we see that the estimated difference of MCC lines on surges is the same, at -0.15, and still not statistically significant. Because this analysis excluded nonconnected households, which are a self-selected group, the estimated difference in power surges between MCC and non-MCC lines should be interpreted with caution.

lines were often not placed in the optimal locations to facilitate household connections and TANESCO lacked the capacity and materials to serve all of its customers.

2. Energy use

The T&D lines had no clear impact on the overall amount of energy used by households, but it increased grid electricity use while reducing use of nongrid electricity; it also increased use of electric tools and appliances and amount of light consumed and reduced mobile phone recharge expenses (Tables V.3 and V.4).

The T&D lines had no clear impacts on the primary outcomes in the domain of energy use—amount of electricity from any source and amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by the household (Table V.3). The estimated impacts on these outcomes are not statistically significantly different from zero. In view of the positive impact on the fraction of households connected to the grid, the finding of no clear impact on overall electricity use is unexpected.

The somewhat puzzling result seems to reflect the substitution of nongrid electricity, mainly from generators, for grid electricity. We estimate that the T&D lines increased by 8.0 kWh the monthly amount of grid electricity used by households (for a relative increase of 89 percent) and, at the same time, reduced the use of nongrid electricity by 5.3 kWh (for a relative reduction of 58 percent). The reduction in nongrid electricity use is supported by the reduction by 9 percentage points in the fraction of households owning a generator (for a relative reduction of 29 percent).[45] These estimates are all statistically significant at the 1 percent level. The substitution of grid electricity for nongrid electricity (from generators and car batteries) is likely a function of the lower cost of grid electricity. Apart from increasing the use of grid electricity, the T&D lines had no clear impacts on the use of kerosene or solid fuel. As household get connected to grid electricity, use of liquid fuels such as kerosene could decrease if they were using kerosene lamps as their main source of light. But as suggested in Peters and Sievert (2016) and Bensch et al. (2015), African countries may not experience the same dramatic reduction in kerosene use found in other regions because kerosene is already being replaced by dry cell batteries in nonelectrified households.

Although there was no statistically significant increase in energy use, the substitution of grid electricity for nongrid electricity may allow 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. Thus, much of the fuel consumed by generators may go to waste. In contrast, households only pay for the grid electricity they actually use. Thus, grid electricity can allow households to get more use out of their appliances, tools, and light bulbs per unit of electricity in comparison to generators. Indeed, the T&D lines seem to have translated into households' increased use of electric tools and appliances, increased consumption of light, and reduced expenditures on recharging mobile phones. We found that the T&D lines had a positive impact of 0.5 on the number of electric tools and appliances used in a household

[45] We also estimated (not reported in our main table) a negative impact of 5.10 on hours of car battery use from a mean of 9.26 in the comparison group. The impact is statistically significant at the 5 percent level. We did not find clear impacts on the monthly amount of electricity from dry cell batteries used by households or on the percentage of households using dry cell batteries as a source of fuel.

while increasing the fraction of households that own a television by 3 percentage points (for relative increases of 14 and 15 percent, respectively). The T&D lines also increased hours per month of use of electric tools and appliances by about 115 hours as well as monthly hours of use of electric fans by 1.6 hours (for relative increases of 24 and 86 percent, respectively). The estimated impact on the monthly consumption of light was 76, 821 lumen-hours, a relative increase of about 32 percent over the comparison group mean of 236,050 lumen-hours. However, the estimated impact on the total monthly costs of light is not statistically different from zero; the imprecise estimate reflects the large underlying variation in the cost of light across households.

We also found that, even though the T&D lines had no clear impact on a household's likelihood of owning a mobile phone, it reduced the cost per recharge of mobile phones by 21 TZS (about 1 U.S. cent, not shown) and the household's monthly expenditure on mobile phone recharge by 558 TZS or 0.26 USD (for relative reductions of 15 and 22 percent, respectively). We estimated that 30 percent of intervention households charged mobile phones at home compared to 27 percent of comparison households (result not shown). The modest 3 percentage point impact is significant at the 10 percent level and partly explains the decrease in the cost of charging phones.

Table V.3. Household-level T&D impacts on energy use

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Primary outcomes				
Monthly amount of electricity used by household from any source (kWh)	18.11	2.59	1.73	0.13
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	5.24	2.07	2.35	0.38
Secondary outcomes				
Household uses electricity from any source except batteries	0.27	0.02	0.01	0.20
Household owns a generator powered by liquid fuel/solar/hydro/wind	0.31	-0.09	0.02***	0.00
Monthly amount of				
Grid electricity used by household (kWh)	9.00	8.00	1.32***	0.00
Nongrid electricity used by household (kWh)	9.16	-5.28	1.32***	0.00
Kerosene used by household (liter)	1.70	-0.32	0.33	0.34
Solid fuel used by household (kg)	159	-11	16	0.52
Number of electric tools/appliances owned by household	3.61	0.51	0.15***	0.00
Household owns a television	0.19	0.03	0.01**	0.03
Monthly hours of electric				
Tools/appliances used by household	489	115	32***	0.00
Fan used by household	1.83	1.57	0.74**	0.04
Monthly amount of light consumed by household (lumen-hours)	236,050	76,821	21,888***	0.00
Total monthly cost of light consumed by household (TZS)	15,437	-14,604	12,621	0.25

Table V.3. *(continued)*

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Household owns at least one mobile phone	0.85	0.00	0.01	0.71
Monthly household costs for mobile phone recharge (TZS)	2,518	-558	129***	0.00

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 4,467 in the intervention group and 4,430 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

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

Table V.4. Community-level T&D impacts on energy use

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Secondary outcomes				
TANESCO informed households				
Fully about low tariff requirements	0.20	0.11	0.05**	0.03
Partially about low tariff requirements	0.23	0.28	0.06***	0.00
Community has access to				
Kerosene	0.94	0.01	0.03	0.77
Diesel/gasoline	0.83	0.00	0.03	0.86
Firewood, charcoal, or dung	0.92	0.07	0.03**	0.04

Source: Tanzania energy sector baseline and follow-up community surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for community-level explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 358 communities, with 178 in the intervention group and 180 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using community size (number of households) as weights to make the community-level results apply to the households in those communities.

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

The T&D lines had positive impacts on a few other secondary outcomes in the energy use domain as measured at the community level. According to the community survey respondent reports, the activity increased—by 11 and 28 percentage points, respectively—the fraction of households in communities in which TANESCO fully and partially informed households of the low-cost tariff requirements (for relative increases of 55 and 121 percent, respectively).[46]

[46] Each community leader reports only on conditions in their community at the community level and not at the household level. However, we weighted the results by the numbers of households in each community. Hence, the results are relevant for the fraction of households living in communities in which TANESCO provided different levels of information. A community is designated as one where households are fully informed if its leader reported that TANESCO informed households of all requirements for the low-cost connections. It is designated as partially informed if TANESCO is reported to have informed households about one of the two requirements. The two requirements are that 1) a household must consume little electricity and 2) it must pay the regular tariff and monthly service charge for a few months before paying the low-cost tariff.

TANESCO's offer of a low-cost tariff plan without a monthly service charge was applicable only to customers willing to consume no more than 75 kWh per month. If, however, customers were unaware of the limit, they could have unknowingly consumed more than 75 kWh per month and thus would be subject to a monthly fee charged by TANESCO. In fact, the findings based on qualitative data from the study communities (Miller et al. 2015) reflected concerns about the degree to which TANESCO informed households about the consumption limit. In that context, it is encouraging that the perception of how well TANESCO informed community members is somewhat better in the T&D communities than in the non-T&D communities, though, even with the intervention, about half of the households remained uniformed about the low-tariff option. The T&D lines also increased by 7 percentage points the share of households in communities with access to solid fuel, such as firewood, charcoal, or dung.[47] It is unclear why or how the T&D lines would lead to such an increase.

3. Education and child time use

The T&D lines had a positive impact on the fraction of households in communities with electrified schools, but no substantial impact on the pattern of children's time use (Tables V.5 and V.6).

In the domain of education and child time use, the T&D lines had a positive impact on the primary outcome measured at the community level, though not on the primary outcome measured at the household level. The activity increased by 18 percentage points the share of households in communities with schools with electricity (for a relative increase of 51 percent); the estimate is statistically significant at the 1 percent level. Thus, more schools had electricity as new lines were installed in the intervention communities. Consistent with this impact, the activity increased the fraction of households with any child age 5 to 14 attending a school with electricity (a secondary outcome reported in Table V.6). However, the activity had no clear impact on the time that children age 5 to 14 spent on studying at night, the primary household-level outcome.

The T&D lines had limited impacts on the secondary outcomes in the education domain. In particular it had no clear impacts on the distances from the community to the nearest preprimary, primary, and secondary schools. Such impacts might have occurred if electrification inspired increased investments in other areas, including schools, both to provide better services for current residents and for new residents attracted by the availability of the grid. Construction of new schools would, in turn, decrease average distance to schools from the community. Our findings suggest that while the T&D lines increased the number of existing schools that are electrified, discussed above, it did not facilitate the construction of new schools.

It also did not clearly affect the pattern of children's daily time use, except the time they spent on watching television and sleeping. The estimated impact of 0.12 hours (or about seven minutes) on the time children spent on watching television (for a relative increase of 44 percent and significant at the 1 percent level) is consistent with the positive impact on households

[47] Access to these solid fuels are defined as the availability of a place in the community where these items can be purchased.

owning a television. The T&D lines also increased the time that children slept at night by a small amount—0.08 hours (or about five minutes) compared to those in the comparison households (for a relative increase of less than 1 percent); the estimate is statistically significant at the 10 percent level. We speculate that increased use of electric fans (as shown in Table V.3) among households in the T&D intervention group may help explain this small increase in children's time spent sleeping, as the use of a fan may enable children to sleep more comfortably.

Table V.5. Community-level T&D impacts on education and child time use

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Primary outcomes				
Community has electrified school(s)	0.35	0.18	0.06***	0.01
Secondary outcomes				
Distance from community to nearest				
Preprimary school (km)	3.32	-0.04	0.11	0.71
Primary school (km)	1.61	-0.01	0.04	0.89
Secondary school (km)	3.12	-0.67	0.93	0.48

Source: Tanzania energy sector baseline and follow-up community surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for community-level explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 358 communities, with 178 in the intervention group and 180 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using community size (number of households) as weights to make the community-level results apply to the households in the communities of interest.

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

Table V.6. Household-level T&D impacts on education and child time use

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Primary outcomes				
Average hours per day children (age 5 to 14) spend studying at night[a]	0.40	-0.02	0.03	0.44
Secondary outcomes				
Average hours per day children (age 5 to 14) spend in total studying	0.68	-0.02	0.04	0.56
Average hours per day youth (age 15 to 24) spend				
Studying at night	1.27	0.09	0.08	0.31
In total studying	1.73	0.07	0.10	0.47
Hours children (age 5 to 14) spent in last 24 hours[b]				
Collecting water and fuel	0.83	0.01	0.07	0.83
Performing other household chores	0.64	-0.02	0.03	0.55
On leisure/entertainment	2.22	0.06	0.11	0.58
Watching television[c]	0.27	0.12	0.04***	0.00
Sleeping at night	9.14	0.08	0.04*	0.07

Table V.6. *(continued)*

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Fraction of children in household age 5 to 14 attending a school	0.79	-0.01	0.01	0.31
Household has any child age 5 to 14 attending a school with electricity	0.18	0.06	0.02**	0.01

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 4,467 in the intervention group and 4,430 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

[a] Parents were asked how many hours per day each child spends studying during the day and at night, and these numbers were averaged across all children of that age in the household. For other activities, parents were simply asked how much time one specific child age 5-14 spent on that activity during the past 24 hours.

[b] The next five outcomes are based on questions that were asked about only one child in each home.

[c] Time spent watching television is a component of the measure of time spent on leisure/entertainment.

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

4. Health and safety

The T&D lines had no clear impact on access to electrified health facilities or on health problems, but it did improve perceived safety at night (Tables V.7 and V.8).

The T&D lines had no clear impact on whether communities had a health facility with electricity (the community-level primary outcome in the health and safety domain), even though it may have reduced the distance to diagnostic services requiring electricity. The estimated impact on whether communities had a health facility with electricity (that is, a dispensary, health center, diagnostic laboratory, or hospital) is not statistically significant. The activity also had no clear impacts on whether communities had a health facility open at night or the average distance from the community to the nearest health facility. However, the activity reduced the average distance from the community to facilities that provided X-ray services, malaria tests, and HIV tests (but not vaccination services). The reductions in distances range between 21 and 27 percent of the distances for the comparison communities and are statistically significant at the 10 percent level. One possible explanation is that the line extensions improved the availability of electricity, for example from electricity provided with a generator run for only a few hours per day to grid electricity available for longer hours, which now allows the electrified facilities to offer these services.

The T&D lines had no clear impacts on the two primary outcomes at the household level—the fraction of youth age 15 to 24 with health problems and the fraction of children age 5 to 14 with health problems in the last seven days. Our measures of health problems focused on headaches, respiratory problems, and vision problems—health issues that could potentially be affected in the short to medium term by changes in the quality and availability of light as well as by reduced indoor air pollution. The activity also had no clear impacts on outcomes related to adult health, internal and external pollution, information on health issues related to family planning and HIV, and family planning behaviors (Table V.8).

Even in the absence of clear impacts on health-related outcomes, the T&D lines seem to have had some impact on perceived safety at night. According to community survey respondent reports, the activity increased by 22 percentage points the share of households in communities with outside light available on a cloudy night (for a relative increase of 35 percent). Based on the community survey respondent's assessment of how male and female residents felt about safety at night, we estimate that the T&D lines improved the perceived level of safety at night for men but not for women (Table V.7).[48]

Table V.7. Community-level T&D impacts on health and safety

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Primary outcomes				
Community has electrified health facility (dispensary, health center, diagnostic laboratory, hospital)	0.29	0.08	0.07	0.22
Secondary outcomes				
Community has a health facility open at night	0.26	0.01	0.05	0.91
Distance from community to nearest health facility (km)	1.98	-0.50	0.37	0.18
Distance from community to obtain				
Vaccination service (km)	3.08	-1.64	1.13	0.15
X-ray service (km)	33.81	-7.89	4.48*	0.08
Malaria test (km)	4.51	-1.23	0.69*	0.08
HIV test (km)	3.93	-0.83	0.45*	0.07
Community has light available on a cloudy night	0.63	0.22	0.06***	0.00
Perception of women's safety at night				0.76
Feel very safe	0.12	-0.01		
Feel somewhat safe	0.57	0.06		
Feel very unsafe	0.31	-0.04		
Perception of men's safety at night			*	0.08
Feel very safe	0.18	0.02		
Feel somewhat safe	0.71	0.03		
Feel very unsafe	0.11	-0.05		
Most community members have piped water	0.36	-0.02	0.04	0.67
Community has a police post	0.18	0.05	0.98	0.33

Source: Tanzania energy sector baseline and follow-up community surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for community-level explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 358 communities, with 178 in the intervention group and 180 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using community size (number of households) as weights to make the community-level results apply to households in the communities of interest. The statistical significance of the results for perceived safety of female and male residents at night is calculated across the three levels of these outcomes (very safe, somewhat safe, very unsafe).

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

[48] If most of the community survey respondents were male, it is possible that they were less aware of perceived safety issues among females versus males in their communities.

At the household level, we asked respondents if they thought communal light was sufficient, if they felt safe walking at night, if they felt that the community lights helped reduce crime, and if they felt that the community lights helped keep them safe from animals at night. We summarized the measures by calculating whether the respondent answered positively to at least one of the questions, more than half of the questions, or all the questions (Table V.8).

Table V.8. Household-level T&D impacts on health and safety

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Primary outcomes				
Fraction of youth age 15 to 24 in the household with health problems in last 7 days[a]	0.26	-0.02	0.02	0.37
Fraction of children age 5 to 14 in the household with health problems in last 7 days[a]	0.29	0.00	0.02	0.78
Secondary outcomes				
Household has a member age 15 to 24 who missed work in the last 30 days due to illness	0.19	-0.02	0.02	0.35
Monthly amount of internal pollution from soot (grams of black carbon)	156.06	17.87	18.61	0.34
Monthly amount of external pollution from carbon (kg CO_2)	289.43	-12.58	29.18	0.67
Household has received family planning information from television/radio/internet/telephone in last 30 days	0.44	0.02	0.02	0.43
Household survey respondent currently uses family planning method	0.33	0.01	0.02	0.49
Household received HIV information from television/radio/internet/telephone in last 30 days	0.43	0.01	0.02	0.59
Household whose last hospital visited had grid electricity at night	0.33	0.03	0.02	0.23
Respondent feels safe at night by				
All measures of safety[b]	0.06	0.06	0.01***	0.00
At least one measure of safety[b]	0.66	0.15	0.02***	0.00
More than half of the measures of safety[b]	0.29	0.20	0.03***	0.00
Household had				
A major fire in home since 2011	0.04	0.00	0.01	0.92
A fire caused by electric source since 2011	0.00	0.00	0.00	0.66
A fire caused by nonelectric source since 2011	0.04	0.00	0.01	0.89

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 4,467 in the intervention group and 4,430 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

[a] Health problems include headaches; vision and respiratory problems.

[b] The measures of perceived safety are based on four items in the follow-up household survey covering whether communal lights around households and businesses are sufficient to help walk at night, whether the respondent feels safe walking in the community at night, and whether lights in the community provide some protection against crime and wild animals.

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

By using all three summary measures, we found evidence that the T&D lines improved the perception of safety. The findings support the view that availability of electric lights outside of the house at night improved the perceived safety of moving around the community at night. We also examined household measures of safety by gender of the household head and found mixed results, with one of the three measures of safety showing statistically significant differential impacts by gender of the household head (results not shown). In other words, the household survey provided no clear evidence in support of the finding from the community survey that the T&D lines improved the perception of safety among men but not among women. Finally, the activity had no clear impacts on household fires caused by electric or nonelectric sources.

5. Business and adult time use

The T&D lines increased the presence of electrified businesses at the community level but had no clear impacts on economic activities and limited impact on adult time use (Tables V.9 and V.10).

The T&D lines increased the fractions of households in communities with businesses connected to the national grid. It increased by 44 percentage points the share of households in communities with at least one business with electricity (for a relative increase of 85 percent). We found similar impacts on a connected repair shop, tea/coffee shop, guest house or hotel, or other businesses (Table V.9). We also found that a greater share of businesses in the intervention communities was connected to the grid relative to the comparison communities; on average, the T&D lines increased the share of businesses connected by 16 percentage points (for a relative increase of 48 percent), as underscored by connections to the grid among a larger share of weekly markets, restaurants and tea/coffee shops, telephone repair shops, hotels or guest houses, salons, grain mills, oil mills, mobile money banking centers, and welding and metal fabrication centers than those in the comparison communities.

The T&D lines had a positive impact on the percentage of businesses with electricity but showed no clear impacts on the fraction of households operating any IGA, household revenue from IGAs, or paid employment of a household member (Table V.10). The activity increased the fraction of households operating an IGA connected to electricity by 2 percentage points (for a relative increase of 33 percent); the estimate is statistically significant at the 1 percent level. The lack of clear impacts on household revenue from IGAs is reflected at the community level by the estimate that the activity had no clear impact on the community's main source of income.

The T&D lines had no clear impacts on the amount of time women and men spent on productive activities (wage labor, other IGAs), but it seemed to have increased women's and men's time spent collecting water and fuel, at home with family, and watching television (Table V.10). For women, on average, the activity increased daily time spent on collecting water and fuel by about 8 minutes, at home with family by 13 minutes, and watching television by 5 minutes (for relative increases of 11, 11, and 28 percent, respectively). For men, some impacts were relatively larger than those for women; on average, the activity increased daily time spent on collecting water and fuel by about 7 minutes, at home with family by about 8 minutes, and watching television by 5 minutes (for relative increases of 24, 6, and 25 percent, respectively). The estimated impacts on women and men spending more time with family and on both men and women watching television align with the perceived benefits noted by qualitative focus group participants in the study communities (Miller et al. 2015). For women, the activity also increased daily time spent on nonwage labor or other productive activities by 9 minutes and cooking, processing and preparing food by about 6 minutes (for relative increases of 17 and 3 percent, respectively), perhaps indicating that women "extended" their day to perform some household work at night. The ability to shift work to different times of the day may also help explain the additional time that both men and women spent on collecting fuel and water. The activity increased by 2 minutes per day the time that men in intervention households spent on reading and studying (for a relative increase of 42 percent).

Table V.9. Community-level T&D impacts on business and adult time use

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Primary outcomes				
Community has at least one electrified business	0.52	0.44	0.04***	0.00
Secondary outcomes				
Community has an electrified				
Repair shop	0.30	0.19	0.07***	0.00
Tea/coffee shop, guest house, or hotel	0.47	0.30	0.06***	0.00
Other businesses	0.52	0.44	0.04***	0.00
Fraction of establishments in community that are electrified				
All businesses	0.33	0.16	0.05***	0.00
Weekly markets	0.01	0.03	0.01**	0.02
Agricultural repair shops	0.09	0.03	0.05	0.51
Vehicle repair shops	0.25	0.02	0.04	0.63
Restaurants, tea/coffee shops	0.22	0.10	0.04**	0.02
Telephone repair shops	0.39	0.32	0.09***	0.00
Carpentry shops	0.17	0.03	0.04	0.45
Hotels/guest houses	0.34	0.17	0.05***	0.00
Hair salons/barber shops	0.41	0.38	0.11***	0.00
Tailor shops	0.17	-0.01	0.04	0.87
Newspaper shops	0.04	-0.02	0.03	0.47
Cafes	0.13	0.02	0.05	0.75
Grain mills	0.40	0.22	0.08***	0.01
Saw mills	0.25	0.07	0.06	0.23
Oil mills	0.08	0.13	0.08*	0.08
Mobile money banking	0.35	0.16	0.08**	0.03
Welding and metal fabrication	0.35	0.24	0.10**	0.02
Car battery charging shops	0.31	0.03	0.09	0.72
Community has an electrified post office	0.05	0.01	0.02	0.73
Community has farming, fishing, livestock, or hunting as main source of income	0.76	-0.03	0.03	0.28

Source: Tanzania energy sector baseline and follow-up community surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for community-level explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 358 communities, with 178 in the intervention group and 180 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix D contains sample sizes for each outcome. We calculated statistics by using community size (number of households) as weights to make the community-level results apply to the households in the communities of interest.

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

Table V.10. Household-level T&D impacts on business and adult time use

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Primary outcomes				
Household operates any IGA	0.63	0.01	0.02	0.70
Secondary outcomes				
Household operates an IGA that uses grid electricity	0.07	0.02	0.01***	0.01
Household's monthly revenue from IGA (TZS)	157,028	-1,199	20,726	0.95
Household's annual revenue from IGA (TZS)	1,432,262	174,355	219,707	0.43
Household has at least one member who is a paid employee	0.18	0.00	0.01	0.94
Women's time use: Hours per day on each type of activity				
Wage labor (agricultural and nonagricultural)	0.64	0.07	0.08	0.34
Nonwage labor/other productive activities (farming and other activities)	0.91	0.15	0.08**	0.04
Other IGA	1.19	0.06	0.08	0.45
Household chores and child care	2.45	-0.02	0.07	0.80
Collecting fuel and water	1.30	0.14	0.07**	0.05
Cooking, processing, and preparing food	3.27	0.11	0.06*	0.10
Reading and studying	0.03	0.00	0.01	0.62
Socializing and resting	4.63	0.02	0.09	0.81
Time spent at home with family[a]	2.07	0.22	0.09**	0.01
Watching television[a]	0.26	0.07	0.03**	0.01
Sleep at night	8.62	0.02	0.04	0.54
Men's time use: Hours per day on each type of activity				
Wage labor (agricultural and nonagricultural)	1.53	0.07	0.14	0.62
Nonwage labor/other productive activities (farming and other activities)	1.35	0.07	0.10	0.48
Other IGA	1.80	-0.14	0.13	0.28
Household chores and child care	0.46	0.00	0.04	0.93
Collecting fuel and water	0.45	0.11	0.04**	0.01
Cooking, processing, and preparing food	0.28	-0.02	0.03	0.51
Reading and studying	0.07	0.03	0.01*	0.05
Socializing and resting	5.81	0.06	0.12	0.64
Time spent at home with family[a]	1.97	0.13	0.07*	0.08
Watching television[a]	0.36	0.09	0.04**	0.02
Sleep at night	8.41	0.04	0.05	0.35

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 4,467 in the intervention group and 4,430 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

[a] Time spent at home with family and watching television are components of the measure of time spent on socializing and resting.

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

6. Economic well-being

The T&D lines had a large positive impact on the price of residential land but no clear impacts on other measures of economic well-being (Tables V.11 and V.12).

The T&D lines had a large positive impact on the primary community-level outcome—the price of residential land—and a positive impact on new health centers (Table V.11). The activity increased the natural log of the price per acre of residential land by 0.34, which implies that the T&D lines increased land prices by about 40 percent.[49] The T&D lines had no clear impact on the price per acre of farmland, most of which is probably not located near the new lines. The T&D lines also had a 9 percentage point impact on having new water supply facility, built after 2011, and an 8 percentage point impact on having a new health center, built after 2011 (for relative increases of 22 percent and 42 percent, respectively). In contrast, we saw no statistically significant evidence of impacts on distance to schools. One possible explanation for this result is that most communities already had at least some schools. While this seems possible for the lower grade levels it seems less likely for secondary schools. Interestingly, while not statistically significant, the point estimate for the estimated impact of T&D on distance to secondary schools was negative (as expected) and large.

The estimated impacts of line extensions incorporate both direct impacts of line extensions on the outcomes covered by our study and indirect impacts that are caused by related investments that were affected by the line extensions, such as efforts to improve schools, water supplies, health centers, and roads. The results in Table V.11 suggest that these indirect impacts may be fairly modest—indeed the impacts are not statistically significant for schools and roads, and actually negative and statistically significant for water—only the impacts on health centers are positive and statistically significant. A similar point can be made about the potential for indirect impacts of line extensions on these outcomes that occur because low-cost connections were offered in 15 percent (27 out of 178) of the line extension communities, as discussed in Chapter III.

In the domain of economic well-being, however, the T&D lines had no clear impacts on household outcomes. Given that we expected to find a positive impact of the T&D lines on the consumption of electricity, we wanted to explore nonelectric consumption as the primary household-level outcome related to economic well-being. Our estimates show that the activity had no clear impacts on nonelectric consumption or on the secondary outcomes at the household level, including annual income, per capita total daily consumption, per capita daily income, and total household assets (Table V.12).

[49] Like the other community-level outcomes, price per acre of residential land is also reported by the community leaders who responded to the survey and is an imperfect measure of the actual price. However, as long as there are no systematic differences in the extent of this imperfect reporting between intervention and comparison community leaders, the estimated impacts on price per acre represents the causal impacts of the T&D lines. Also community leaders may be more aware of most recent land sales that occur in a community than most households since the leaders are likely, on average, to be in contact with more people as part of their leadership activities.

Table V.11. Community-level T&D impacts on economic well-being

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Primary outcomes				
Natural log of price per acre of residential land in community	14.16	0.34	0.16**	0.03
Secondary outcomes				
Natural log of price per acre of farmland in community	13.21	0.19	0.16	0.22
Community is one				
In which most people have mobile phones	0.20	0.06	0.04	0.21
With a new school built after 2011	0.50	0.03	0.07	0.73
With a new water supply built after 2011	0.41	-0.09	0.04**	0.03
With a new health center built after 2011	0.19	0.08	0.03***	0.01
With new roads built after 2011	0.45	0.06	0.06	0.33
Community with plans within two years for new or upgraded				
School	0.50	0.07	0.09	0.45
Public water supply	0.49	-0.03	0.05	0.60
Health center	0.40	0.09	0.08	0.22
Roads	0.46	-0.03	0.10	0.74
Market	0.29	0.10	0.06	0.13

Source: Tanzania energy sector baseline and follow-up community surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for community-level explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 358 communities, with 178 in the intervention group and 180 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using community size (number of households) as weights to make the community-level results apply to the households in the communities of interest.

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

Table V.12. Household-level T&D impacts on economic well-being

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Primary outcomes				
Annual household nonelectricity consumption (TZS)	3,401,477	-105,415	126,578	0.41
Secondary outcomes				
Annual household income (TZS)	2,847,584	-188,237	242,960	0.44
Household per capita total daily consumption (TZS)	1,941	-54	76	0.48
Household per capita daily income (TZS)	1,633	-146	163	0.37
Household consumes less than $1 per day per person	0.76	-0.02	0.02	0.33
Household consumes less than $2 per day per person	0.93	0.00	0.01	0.54
Total household assets (TZS)	59,511,028	-6,671,368	30,377,716	0.83
Household lives in an electrifiable dwelling based on wall and roof materials	0.75	-0.02	0.02	0.46
Average number of rooms in household for sleeping	3.72	-0.03	0.07	0.61
Household has a flush toilet	0.22	-0.01	0.02	0.59
Household has piped water in rainy and dry seasons	0.06	0.00	0.01	0.67

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 4,467 in the intervention group and 4,430 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

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

7. Composition and mobility

The T&D lines had no clear impacts on outcomes related to composition and mobility of households in the community (Tables V.13 and V.14).

The T&D lines had no clear impact on the total number of households in the community based on the household listing data. The activity also had no clear impacts on nearly all of the secondary outcomes covering rates of in- and out-migration, rates of formation of new households, and change of community boundaries since 2011 (Tables V.13 and V.14). The only other community-level outcome for which the estimated impact is statistically significant is the identification of the community as an urban community at follow-up. The T&D lines reduced by 11 percentage points the likelihood that a community would be urban (for a relative reduction of 28 percent), with the estimate statistically significant at the 1 percent level. We expected that the T&D lines might increase in-migration and therefore increase the fraction of communities labeled as urban. Instead we found the opposite. It is not clear why the T&D lines would produce such an impact.[50] We also found no evidence of impact on the secondary outcomes at the

[50] This estimated impact on the likelihood that a community is urban may also reflect inaccurate reporting on the urban-rural status at the time of either the baseline or follow-up survey. As noted in Chapter IV, it is possible that some leaders in rural baseline communities may have incorrectly assumed that their communities would be changed to urban since they were getting new lines. Also, more generally, there could be very reasonable misunderstandings about whether and when the official status of a community might change from rural to urban given that there are a number of steps involved in making such changes and the decision to change could be reversed during this process.

household level as related to mobility within the community or selective out-migration per baseline income.[51]

Table V.13. Community-level T&D impacts on composition and mobility

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Primary outcomes				
Number of households in community (based on household listing)	202.47	8.42	17.17	0.64
Secondary outcomes				
Fraction of households in community at follow-up that are in-migrants since 2011	0.02	0.00	0.00	0.67
Fraction of households in community at follow-up that are newly formed since 2011	0.02	0.00	0.00*	0.08
Community identified as *mtaa* – urban	0.39	-0.11	0.04***	0.01
Community boundaries changed since 2011	0.35	-0.02	0.05	0.72

Source: Tanzania energy sector baseline and follow-up community surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for community-level explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 358 communities, with 178 in the intervention group and 180 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using community size (number of households) as weights to make the community-level results apply to the households of interest.

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

Table V.14. Household-level T&D impacts on composition and mobility

Follow-up outcome	Comparison mean	Impact	Standard error	*p*-value
Secondary outcomes				
Household moved within community since 2011	0.08	0.01	0.01	0.26
Household out-migrated since 2011	0.03	0.00	0.01	0.49
Household out-migrated since 2011 (among those with baseline income above district median)	0.03	0.01	0.01	0.42
Household out-migrated since 2011 (among those with baseline income below district median)	0.03	-0.01	0.01	0.14

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 4,467 in the intervention group and 4,430 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

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

[51] We also found no clear impacts on household size. This incorporates net movement into and out of the household as well as fertility; in future research it might be worth considering additional analyses that focuses in on fertility.

B. Findings for subgroups

In this section, we describe findings from the T&D impact analysis for subgroups that we define in terms of three baseline household characteristics—gender of the household head, age of the household head (younger than age 25; age 25 or older), and the household's income quartile—and one baseline community characteristic, namely, the community's urban-rural status. Tables with estimated impacts for all subgroups appear in Appendix E.

1. Gender of household head at baseline

The T&D lines had a larger positive impact on connection rates among male-headed households than among female-headed households (Appendix Table E.2b).

The T&D lines had positive impacts on connection rates among male- and female-headed households, with the impact for male-headed households 3 percentage points larger than that for female-headed households; the differential impact was statistically significant at the 10 percent level. None of the other estimated impacts is statistically significantly different by gender of the household head.

2. Age of household head at baseline

The T&D lines had a larger positive impact on connection rates among households with a head age 25 years or older than among households with a head younger than age 25 (Appendix Table E.2c).

We hypothesized that households with younger heads might be more mobile and more likely to take advantage of new lines. However, the T&D lines had more positive impacts on connection rates among households with a head age 25 years or older. The differential with the subgroup of households with a head younger than age 25 is 12 percentage points and is statistically significant at the 5 percent level. One explanation for the households with older heads connecting at higher rates is related to their ability to afford the connection costs; average total annual income of households with older heads was higher at baseline than that of households with younger heads by 790,197 TZS. In addition to the difference in connection rates, the T&D lines had a larger positive impact on electricity use and total non-electric consumption among households with a head age 25 years or older, although the differences were significant only at the 10 percent level. Relatively few households had a head younger than age 25—235 households, with 122 in the comparison group and 113 in the intervention group. The relatively small sample size of households with younger heads is an important consideration when interpreting results for these subgroups.

3. Urban versus rural communities at baseline

Estimated impacts by urbanicity were mixed (Appendix Table E.2d).

The T&D lines had an undesirable negative impact on the average hours per day that children age 5 to 14 spend on studying at night among households in urban areas. The impact was positive, though not statistically significant, in rural areas. Overall, the impact for households in urban areas was 0.14 hours (about 8 minutes) lower than that for households in rural areas, a differential that is statistically significant at the 5 percent level. Given the overall finding that the activity increased the amount of time children spent on watching television, we investigated the possibility that this outcome varied by urban versus rural location. However, we did not find any statistically significant differences (result not shown). At the same time, the T&D lines appeared to have a desirable impact among urban households by reducing the fraction of youth age 15 to 24 with health problems in the last seven days. The impact is different from that among rural households, with a differential of 6 percentage points that is statistically significant at the 10 percent level. However, the impact on the other primary outcome in the domain of health and safety—fraction of youth age 5 to 14 with health problems in the last seven days—was not different between the two subgroups. For none of the other primary outcomes did we find that the estimated impacts differed between urban and rural households.

4. Baseline household income quartile

We found no evidence of differential impacts of line extensions across the income quartiles except for the impacts on connection rates; the T&D lines had larger impacts on connection rates among households with higher baseline incomes (Appendix Table E.2e).

The T&D lines had positive impacts on connection rates in each income quartile, but the impacts increased monotonically from the lowest to the highest quartile. Within each quartile, we found positive and statistically significant impacts of the activity on connection rates, ranging from 5 percentage points in the lowest quartile to 18 percentage points in the highest quartile; the estimated impacts across income quartiles are jointly statistically different from each other at the 1 percent level. We also found that the T&D lines had a statistically significant positive impact on amount of electricity from any source among households in the second and third income quartiles; however, the impacts across income quartiles are not jointly significantly different from each other. The estimated impacts did not clearly differ across the four income quartiles for any of the other primary outcomes.

CHAPTER VI

IMPACTS OF LOW-COST-CONNECTION OFFERS

This page has been left blank for double-sided copying.

Executive summary

Key findings from the evaluation of low-cost-connection offers:

- The low-cost-connection offers under the FS initiative increased connection rates by 13 percentage points to about 31 percent of households in the treatment communities.
- The low-cost-connection offers increased electricity consumption, consumption of grid electricity, ownership of electric tools, time spent watching television, and perceived safety.
- The low-cost-connection offers were associated with increased reported illness among children and youth.
- The FS initiative reduced poverty as measured by per capita daily consumption.

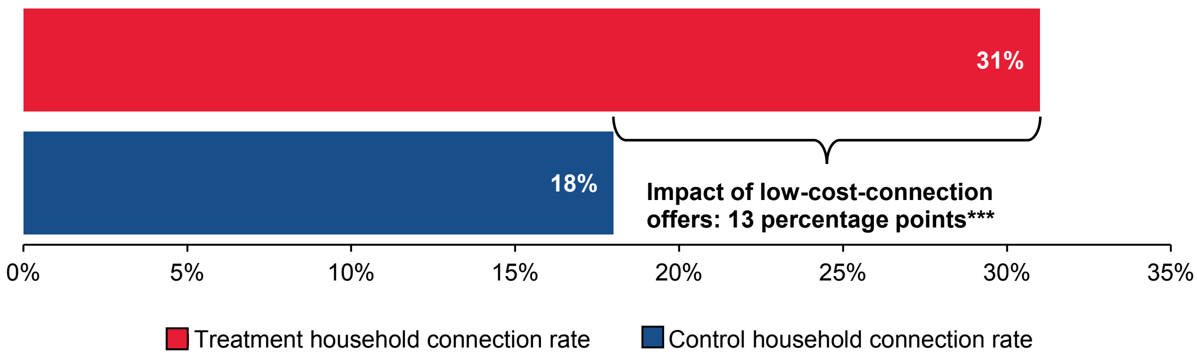
The line extension component of the T&D activity was designed to increase the number of households using grid electricity by giving people access to the national grid. However, access to grid electricity may not result in more connections, especially if connection fees are prohibitively high. Indeed, the connection fee was over 90 percent of average monthly household income. To address this concern, low-cost connections were offered under the FS initiative, which lowered the connection fee by over 80 percent and made materials for 5,800 connections available in 27 randomly selected communties out of the 178 communities that received the new lines as part of the line extension activity. The availability of low-cost connections were publically announced in the communities and made available to customers on a first-come, first-served basis.

The impact evaluation design follows a randomized control trial approach using data from the household surveys. Our treatment group are households in the 27 communities that received the new lines and the low-cost connections; the control group are households in the remaining 151 communities that received the new lines. In contrast to the line extensions evaluation, which estimates the impacts of the new lines on a variety of outcomes, the evaluation of low-cost-connection offers assesses impacts of offering low-cost connections to these new lines on the same set of household outcomes.

Connection rates

The low-cost-connection offers increased connection rates to 31 percent from a baseline connection rate of 18 percent in the control group (Figure ES.VI.1). The estimated impact of the low-cost-connection offers was similar in magnitude to the estimated impact of the line extensions (which included the low cost-offers in 27 of the 178 communities with line extensions); this highlights the importance of connection costs as a barrier to the use of grid electricity in the study communities.

Figure ES.VI.1. Impact of low-cost-connection offers on connection rates



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

Notes: 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 regression adjusted.

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

As a consequence of greater connectivity in the low-cost-connection offers communities, we found that households in the low-cost-connection offers communities used about 1.79 more hours of electricity per day on average. For connected households this means approximately 13.8 hours per day of electricity use.

Low-cost-connection offers impact by urbanicity and other subgroups

- The low-cost-connection offers had no differential impacts by income quartile, urbanicity, gender of the household head, or age of the household head.

Energy use

Households in communities who were offered low-cost connections consumed about 33 percent more electricity (6.61 kWh) from any source than did households who were not offered the low-cost connections. This increased energy consumption may have resulted from a substitution of nongrid electricity for grid electricity; households in low-cost-connection offer communities consumed about 9.6 more kWh per month in grid electricity and consumed about 2.8 fewer kWh per month in nongrid electricity. Like the T&D lines, the low-cost-connection offers increased the use of electric tools and appliances and amount of light consumed and reduced mobile phone recharge expenses.

Education and child time use

The low-cost-connection offers did not clearly increase the amount of time children spent studying at night or in total, as might be hoped, but it did boost the amount of time spent children watching television. We did not find any statistically significant differences for other activities such as collecting fuel and water, sleeping, or performing household chores.

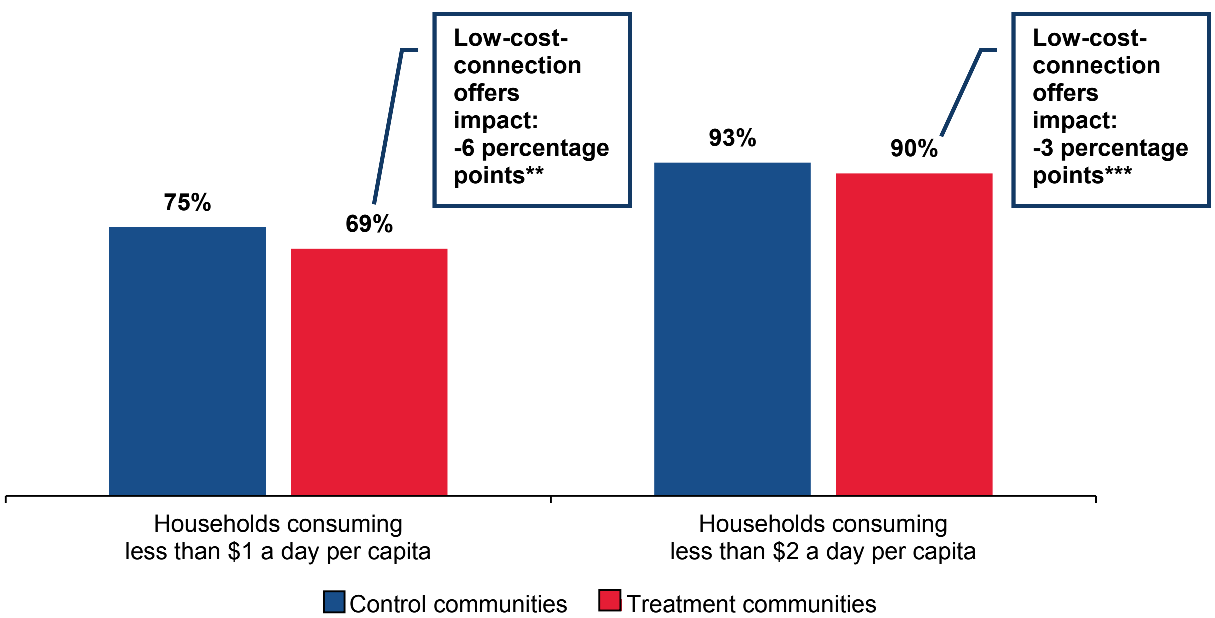
Health and safety

Children in the communities with low-cost-connection offers had more reported illness, but the offers increased perceived safety. About 35 percent of children age 5 to 14 and 30 percent youth age 15 to 24 living in low-cost-connection offer community households reported health problems in the seven days before the follow-up survey. In both cases, the impacts are approximately 7 percentage points. This may be related to the positive impacts on TV watching leading children to stay inside the home longer. Because we did not find any negative impacts on kerosene use, which likely creates pollution in the home and, subsequently, no negative impacts on indoor air pollution, more time spent at home could cause health problems. Respondents in communities with the low-cost-connection offers, however, generally felt safer than those living in communities that did not receive the offer. We asked households if they thought communal light was sufficient, if they felt safe walking at night, if they felt that the community lights helped reduce crime and keep them safe from animals at night. We found that the perception of safety persisted for three summary measures of safety: 17 percent responded feeling safe on all four questions of safety, 63 percent on more than half of the questions, and 87 percent on at least one question. The impacts of the low-cost-connection offers were 5, 7, and 16 percentage points, respectively. We found no statistically significant impacts on the amount of internal or external pollution produced, which is consistent with the lack of clear impacts on liquid fuel.

Business and adult time use

The low-cost-connection offers had no clear impacts on whether the household operated an IGA or had an electrified IGA, but it increased the amount of time women and men spent on wage labor and on watching television. Despite no clear impacts on sleep for children, the low-cost-connection offers reduced the amount of time men and women slept by about 8 and 16 minutes, respectively. This perhaps reflects an increase in the number of options for spending time on other activities at night as a consequence of available electricity.

Figure ES.VI.2. Impacts of low-cost-connection offers on per capita consumption



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

Notes: The FS analysis sample includes 4,467 households, with 632 in the treatment group and 3,835 in the control group. Impact estimates are regression adjusted.

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

Economic well-being and composition and mobility

The low-cost-connection offers had positive impacts on poverty reduction and per capita consumption. The low-cost-connection offers increased total daily per capita consumption by a little less than 0.20 USD. It did not, however, have a clear impact on total household nonelectricity consumption. The difference between these consumption outcomes suggests that household size, as reflected in the per capita measure, partly helps reduce the amount of unexplained variation in the per capita measure. The low-cost-connection offers reduced the percentage of households consuming less than 1 USD a day per capita by six percentage points and 2 USD a day per capita by three percentage points (Figure ES.VI.2). We found no statistically significant impacts on migration. [52]

[52] We also found no clear impacts on household size.

Introduction

The FS initiative was designed to offer lower-cost connections to households in the 27 randomly selected treatment communities from within the evaluation's 178 T&D intervention communities (excluding communities in the Kigoma region). In other words it is designed to estimate the impacts of being in a community selected to have access to low-cost connections and new lines in comparison to being in a community selected only for new lines. The FS initiative (also referred to as the low-cost-connection offers) was deemed necessary given that connection fees were high so even with new lines provided by the T&D activity many households choose not to connect. Indeed, the connection fee was equivalent to over 90 percent of average household monthly income.[53] The expectation was that more households in the treatment communities would connect to the electric grid taking advantage of these lower-cost connections. The impact evaluation design for the FS initiative follows an RCT approach. In this chapter, we first present the main findings from the impact analysis of the FS initiative on household outcomes and then describe the findings from our subgroup analyses.[54] As in the previous chapter, we organize our discussion by domain and, within each domain, first focus on findings for our primary outcomes and then discuss secondary outcomes. Detailed definitions of these outcomes are presented in Appendix C.

A. Main findings

1. Connection rates

The FS initiative increased the fraction of households that are connected to the national grid, have access to an electric pole, and use electricity (Table VI.1).

The FS initiative had a 13-percentage point impact on connection rates, an increase of over 72 percent relative to the comparison group mean of 18 percent; the estimated impact is statistically significant at the 1 percent level. The offer of low-cost connections made as much as or a larger difference in increasing the likelihood that households would connect to the grid compared to the 10 percentage points impacts of bringing just electric lines to the households' communities under the T&D activity (as discussed in Chapter V).

The FS initiative improved access to grid electricity in terms of the ability to connect to the grid without installation of an additional pole and households' relative location to the nearest pole. The FS had a 15 percentage point impact on households' ability to connect without an additional pole. In addition, even though many households in the control communities were located close to the poles, we still found large positive impacts of FS on being located within 30, 40, 50, or 100 meters of a pole. For example, about half of the households in the control communities were situated within 50 meters of a pole and we estimate a 17 percentage point

[53] In rural areas the fee was 177,000 TZS and in urban areas it was 320,960 TZS. Average monthly income in 2015 in the T&D communities was around 190,000 TZS in rural areas and around 250,000 TZS in urban areas. The FS initiative lowered the connection fee to 30,000 TZS in both rural and urban areas.

[54] In this chapter, we present only the FS impact estimates based on household data because the FS was implemented only in the subvillages covered by our household survey and not in the other subvillages also covered by the community survey.

impact of FS on this outcome. We also found positive impacts of FS on being located within 30 meters of a pole using the GPS and listing data.[55]

We consider two potential explanations for the impact of the FS initiative on proximity to a pole. First, perhaps households saw the benefits of the low-cost connections and were able to relocate to be closer to the poles. They could do this by moving to a different dwelling within an existing property, by repositioning their current dwelling within an existing property, by moving to another property they owned, or by purchasing a new property. Given that many dwellings are made of basic materials, moving existing dwellings could be relatively cheap.[56] Second, the July 2012 announcement of the FS initiative coincided with the completion of line installation in some communities, but the announcement took place more than a year before the final installation of all lines in September of 2013 (Chaplin et al. 2015). Because TANESCO generally placed poles in areas where more households and businesses would connect—the ones who would likely be able to pay for connection fees—it is possible that the design engineers' decisions regarding the placement of the poles were influenced by the availability of the FS initiative.[57]

About 20 percent of the households in the FS initiative communities were connected to an MCC line at follow-up versus 8 percent of households in the T&D intervention communities that did not receive the financing scheme. The implication is an impact of 12 percentage points, which is about the same as the impact on overall connection rates. The magnitude of the impact is somewhat surprising given that connections to non-MCC lines were also eligible for the FS initiative. However, it is possible that many households believed that they could only use FS to connect to MCC lines. It is also possible that many households living close to non-MCC lines built before 2011 might have taken advantage of FS had it been offered then, but no longer needed it.

As a consequence of greater access and connectivity in the FS initiative communities, we find a substantial impact on the number of hours during which electricity was available to households. Households in the FS initiative communities used about 1.79 more hours of electricity per day—about 62 percent more than was available to control households—which translates into approximately 13.8 hours per day for households that connected in response to the FS initiative (1.79 hours per day divided by a 0.13 percentage point impact on connection rates, with the assumption that the FS initiative affected only the availability of electricity by affecting connection rates).

---

[55] We used both the GPS and survey data for these analyses because both sources have advantages and disadvantages. The GPS data enable us to explore more cut-points than the survey data, but the GPS data may be less accurate, for reasons discussed in Appendix E.

[56] Basic materials used in building dwellings include grass, earth/mud, sundried and baked bricks, timber, bamboo, iron sheets, cement bricks, and stones.

[57] We also checked to see if the FS initiative influenced the number of poles but found no evidence of that (Chapter IV).

Table VI.1. Estimated FS initiative impacts: Connection rates

Follow-up outcome	Control mean	Impact	Standard error	p-value
Primary outcome				
Household is connected to national grid	0.18	0.13	0.02***	0.00
Secondary outcomes				
Household is connected to				
MCC lines	0.08	0.12	0.03***	0.00
Non-MCC lines built after 2011	0.07	0.00	0.03	0.95
Non-MCC lines built before 2011	0.03	0.02	0.01	0.12
Household has access to grid without additional poles	0.48	0.15	0.04***	0.00
Household is within				
30 meters of nearest electric pole (GPS data)	0.30	0.11	0.05**	0.04
30 meters of nearest electric pole (household listing data)	0.42	0.14	0.05**	0.01
30 meters of nearest electric pole (household survey data)	0.41	0.14	0.04***	0.00
40 meters of nearest electric pole (GPS data)	0.39	0.10	0.06	0.12
40 meters of nearest electric pole (household survey data)	0.48	0.16	0.04***	0.00
50 meters of nearest electric pole (GPS data)	0.44	0.11	0.07	0.12
50 meters of nearest electric pole (household survey data)	0.53	0.17	0.04***	0.00
100 meters of nearest electric pole (GPS data)	0.57	0.09	0.08	0.23
100 meters of nearest electric pole (household survey data)	0.67	0.18	0.04***	0.00
Average years household has been connected to national grid[a]	0.43	0.28	0.09***	0.00
Average hours per day household has grid electricity[a]	2.90	1.79	0.45***	0.00

Source: Tanzania energy sector baseline and follow-up household surveys, follow-up listing of households, and follow-up GPS location data.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 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 specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

[a] The average includes households not connected to the national grid.

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

2. Energy use

The FS initiative increased electricity use, amount of light consumed, and the number of electrical appliances and devices owned and used (Table VI.2).

Overall, households in FS initiative communities consumed about 33 percent more electricity (6.61 kWh) from any source than did non-FS initiative households. We did not find any clear impact on the amount of liquid fuel used.

As for the source of electricity, households in FS initiative communities consumed about 9.6 more kWh per month from grid electricity and consumed about 2.7 fewer kWh per month in nongrid electricity as compared to non-FS initiative communities. We examined the several components that made up our measure of electricity consumption, including flashlight use, kerosene lamp ownership and use, light bulb use, and car battery use. We found that the FS initiative increased the number of hours of light bulb use and reduced the use of car batteries, dry cell batteries, and flashlights but demonstrated no clear effects on kerosene lamp ownership or on the percent of households using dry cell batteries for fuel (results not shown).[58] Households in FS communities were also less likely to have a generator, perhaps partially explaining the reduced consumption of nongrid electricity.

The FS initiative increased the use of light and electrical appliances in general. Households in FS initiative communities consumed about 45 percent more light (129,000 more lumen-hours) than control households. The households also spent more on light, though the latter is statistically significant only at the 10 percent level and is not significant in the linear model without covariates.[59] The FS initiative had larger impacts on light use than T&D lines, consistent with their relative impacts on connection rates. The FS initiative increased the number of electric appliances used by 0.72 from a mean of about 4 and the number of hours of use per month by 217, which translates to about 7 additional hours per day. This measure of number of hours of use sums across appliances so it could mean households increase the hours of use of some appliances by less than 7 hours each. We also found a 5 percentage point impact of the FS initiative on television ownership from a base of 21 percent of control households.[60]

Finally, households in FS initiative communities saved about 540 TZS per month on phone charging (about 20 TZS per charge). As compared to households in the control communities, 28 percent more households in the FS treatment communities charged their phones at home instead of using a charging service (results not shown in the table).

[58] We estimated (not reported in our main table) a negative impact of 0.01 kwh on monthly dry cell battery use from a mean of 0.06 kwh in the control group and a negative impact of 4.58 on monthly hours of car battery use from a control group mean of 4.93 hours per month.

[59] As discussed in Chapter IV we estimated a number of alternative specifications depending on the outcome. In general the results were very similar. However, in a few cases the significance levels changed.

[60] This estimate is not statistically significant in the linear model without covariates.

Table VI.2. Estimated FS initiative impacts: Energy use

Follow-up outcome	Control mean	Impact	Standard error	*p*-value
Primary outcomes				
Monthly amount of electricity used by household from any source (kWh)	20.32	6.61	2.55**	0.01
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	6.61	4.55	7.18	0.53
Secondary outcomes				
Household uses electricity from any source except batteries	0.28	0.08	0.02***	0.00
Household owns a generator powered by liquid fuel/solar/hydro/wind	0.24	-0.06	0.02**	0.01
Monthly amount of				
Grid electricity used by household (kWh)	15.22	9.56	2.19***	0.00
Nongrid electricity used by household (kWh)	5.24	-2.74	1.24**	0.03
Kerosene used by household (liter)	1.33	0.44	0.32	0.17
Solid fuel used by household (kg)	151.28	-19.18	15.76	0.22
Number of electric tools/appliances owned by household	3.99	0.72	0.20***	0.00
Household owns a television	0.21	0.05	0.02***	0.00
Monthly hours of electric				
Tools/appliances used by household	564.43	217.28	48.65***	0.00
Fan used by household	3.00	1.62	1.93	0.40
Monthly amount of light consumed by household (lumen-hours)	286,086	129,332	32,629***	0.00
Total monthly cost of light consumed by household (TZS)	1,598	2,479	1,442*	0.09
Household owns at least one mobile phone	0.84	0.01	0.02	0.45
Monthly household costs for mobile phone recharge (TZS)	2,040	-540	180***	0.00

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

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 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 specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

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

3. Education and child time use

We found no clear impacts of the FS initiative on the primary outcomes covering the amount of time children spent studying, but we did find some suggestive evidence that the FS initiative reduced study time among youth and increased television watching among children (Table VI.3).

The results for hours of studying are mixed. We did not see differences between the FS treatment and control households in the time children age 5 to14 spent studying at night (our primary outcome of interest) or over an entire day. However, youth age 15 to 24 in FS communities spent about 0.17 fewer hours (or about 10 minutes) studying per day; the estimate is statistically significant at the 10 percent level.[61]

[61] This estimate is not statistically significant in the linear model without covariates.

Children age 5 to14 in FS communities also spent about 0.18 more hours (or 11 minutes) per day watching television than did children in non-FS communities. We did not find any statistically significant differences for other activities such as collecting fuel and water, sleeping, or performing household chores.

Table VI.3. Estimated FS initiative impacts: Education and child time use

Follow-up outcome	Control mean	Impact	Standard error	*p*-value
Primary outcomes				
Average hours per day children (age 5 to 14) spend studying at night[a]	0.35	0.02	0.05	0.69
Secondary outcomes				
Average hours per day children (age 5 to 14) spend in total studying	0.64	0.00	0.05	0.98
Average hours per day youth (age 15 to 24) spend				
Studying at night	1.31	-0.05	0.13	0.70
In total studying	1.77	-0.17	0.10*	0.09
Hours children (age 5-14) spent in past 24 hours[b]				
Collecting water and fuel	0.83	0.12	0.08	0.15
Performing other household chores	0.64	0.00	0.05	0.96
On leisure/entertainment	2.33	-0.11	0.18	0.56
Watching television[c]	0.36	0.18	0.05***	0.00
Sleeping at night	9.22	0.05	0.08	0.53
Fraction of children in household age 5 to 14 attending school	0.78	-0.01	0.03	0.66
Household has any child age 5 to 14 attending a school with electricity	0.22	0.04	0.06	0.49

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

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 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 specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

[a] Parents were asked how many hours per day each child spends studying during the day and at night, and these numbers were averaged across all children of that age in the household. For other activities, parents were simply asked how much time one specific child age 5-14 spent on that activity during the past 24 hours.

[b] The next five outcomes are based on questions that were asked about only one child in each home.

[c] Time spent watching television is a component of the measure of time spent on leisure/entertainment.

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

4. Health and safety

The FS initiative made health outcomes worse but increased perceived safety (Table VI.4).

Children age 5 to 14 and youth age 15 to 24 living in FS community households were more likely than children and youth residing in control communities to report health problems in the seven days before the follow-up survey. In both cases, the impacts are approximately 7 percentage points. Youth in FS communities were also more likely to have missed work due to illness in the 30 days before the survey, but the 6 percentage point impact is significant only at the 10 percent level. These results are plausible in part because the FS initiative increased television watching but did not appear to reduce kerosene use or indoor pollution (reported below). Therefore, if increased television watching increased the amount of time spent indoors near polluting fuels, it could have worsened health outcomes. Health outcomes measured included having difficulty breathing; experiencing wheezing, coughing, sneezing, sore throat, nasal discharge, or congestion; and having problems with vision---all of which may be related to indoor air pollution.

Respondents in FS communities generally felt safer than those living in non-FS communities. The perception of safety persisted for three summary measures of safety, with impacts ranging from 5 to 16 percentage points.

The FS initiative had no clear impact on any of the other secondary outcomes in the domain of health and safety. We did not find statistically significant impacts on the amount of internal or external pollution produced which is consistent with the lack of clear impacts on liquid fuel. In addition, even though the FS initiative increased connection rates and use of grid electricity, it did not lead to any increase in the risk of household fires.

Table VI.4. Estimated FS initiative impacts: Health and safety

Follow-up outcome	Control mean	Impact	Standard error	*p*-value
Primary outcomes				
Fraction of youth age 15 to 24 in household with health problems in last 7 days[a]	0.24	0.07	0.03**	0.01
Fraction of children age 5 to 14 in household with health problems in last 7 days[a]	0.28	0.07	0.02***	0.01
Secondary outcomes				
Household has a member age 15 to 24 who missed work in the last 30 days due to illness	0.16	0.06	0.03*	0.08
Monthly amount of internal pollution from soot (grams of black carbon)	171.17	9.27	55.65	0.87
Monthly amount of external pollution from carbon (kg CO2)	280.42	-15.28	33.51	0.65
Household has received family planning information from television/radio/internet/telephone in last 30 days	0.45	-0.03	0.04	0.46
Household survey respondent currently uses family planning method	0.32	0.02	0.02	0.46
Household received HIV information from television/radio/internet/telephone in last 30 days	0.44	-0.02	0.04	0.69
Household whose last hospital visited had grid electricity at night	0.33	0.03	0.04	0.43

TableVI.4. *(continued)*

Follow-up outcome	Control mean	Impact	Standard error	*p*-value
Respondent feels safe at night by[b]				
All measures of safety	0.12	0.05	0.03**	0.05
At least one measure of safety	0.80	0.07	0.03**	0.02
More than half of the measures of safety	0.47	0.16	0.04***	0.00
Household had a major fire in home since 2011	0.04	0.00	0.01	0.95

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

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 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 specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

[a] Health problems include headaches; vision and respiratory problems.

[b] 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 walk at night, (2) whether the respondent feels safe walking in the community at night, (3) whether lights in the community provide some protection against crime, and (4) whether the lights provide protection against wild animals.

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

5. Business and adult time use

The FS initiative had no clear impacts on whether the household operated an IGA or had an electrified IGA, but it increased the amount of time women and men spent on wage labor and on watching television (Table VI.5).

The FS initiative did not have clear impacts on whether the household operated an IGA or whether the IGA was powered by electricity. In contrast, the T&D lines did affect IGA electrification. The implication is that the subsidy may be more important for affecting non–IGA-related use of electricity than for affecting IGA use.

The FS initiative increased time per day on wage labor for both men and women. For women, the FS initiative increased wage labor hours by 0.22 hours, which is 32 percent higher than the control group mean of 0.71 hours; for men, the FS initiative increased wage labor hours by 0.40 hours, a relative increase of 25 percent.

For women the FS initiative also had impacts on sleep, time spent watching television, and time spent reading. Despite no clear impacts on sleep for children, the FS initiative produced negative impacts on sleep for both men and women, perhaps reflecting an increase in the number of options for spending time on other activities at night as a consequence of available electric light. As with children, however, adults in the FS initiative households spent additional time watching television. The impact for men, however, is significant only at the 10 percent level.[62]

[62] The estimated impacts on watching television are statistically not significant for both men and women in the linear model without covariates.

Finally, women in FS communities doubled the amount of time they spent reading, but the amount of time was still small in absolute terms—0.06 hours or about four minutes per day. The FS had no clear impacts on other household activities such as time spent on household chores or child care, time spent collecting fuel or water, and time spent preparing food.

Table VI.5. Estimated FS initiative impacts: Business and adult time use

Follow-up outcome	Control mean	Impact	Standard error	*p*-value
Primary outcome				
Household operates any IGA	0.63	-0.02	0.02	0.34
Secondary outcomes				
Household operates any IGA that uses grid electricity	0.08	0.02	0.02	0.13
Household's monthly revenue from IGA (TZS)	164,434	65,046	53,446	0.23
Household's annual revenue from IGA (TZS)	1,755,975	114,823	599,511	0.85
Household has at least one member who is a paid employee	0.17	0.02	0.02	0.38
Women's time use: Hours per day on each type of activity				
Wage labor (agricultural and nonagricultural)	0.71	0.22	0.11**	0.04
Nonwage labor/other productive activities (farming and other activities)	1.04	0.02	0.13	0.88
Other IGAs	1.27	-0.01	0.15	0.96
Household chores and child care	2.41	0.03	0.13	0.82
Collecting fuel and water	1.42	-0.09	0.12	0.46
Cooking, processing, and preparing food	3.34	0.16	0.10	0.12
Reading and studying	0.03	0.03	0.01**	0.04
Socializing and resting	4.67	-0.30	0.21	0.16
Time spent at home with family	2.24	0.15	0.17	0.40
Watching television	0.32	0.10	0.03***	0.00
Sleep at night	8.66	-0.13	0.06**	0.03
Men's time use: Hours per day on each type of activity				
Wage labor (agricultural and nonagricultural)	1.61	0.40	0.20**	0.04
Nonwage labor/other productive activities (farming and other activities)	1.41	-0.06	0.18	0.73
Other IGAs	1.73	-0.03	0.17	0.85
Household chores and child care	0.46	0.10	0.08	0.24
Collecting fuel and water	0.54	0.11	0.11	0.34
Cooking, processing, and preparing food	0.27	-0.01	0.04	0.86
Reading and studying	0.09	0.03	0.03	0.39
Socializing and resting	5.86	-0.17	0.25	0.50
Time spent at home with family	2.05	-0.02	0.14	0.86
Watching television	0.44	0.14	0.07*	0.06
Sleep at night	8.49	-0.27	0.11**	0.02

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

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 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 specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

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

6. Economic well-being

Unlike the findings from the T&D lines analysis, the FS initiative has positive impacts on per capita consumption and on poverty (Table VI.6).

Our results suggest that providing the FS low-cost-connection offers together with new lines increased economic outcomes compared to only providing new lines. The FS initiative had no statistically significant impact on total household nonelectricity consumption in the year before the survey; such consumption is the primary outcome in the domain of economic well-being. However, we did find impacts on households' total daily consumption per capita (including electricity and nonelectricity). Total daily consumption per capita increased by 365 TZS to over 2,200 TZS (a little more than $1) in households offered the low-cost connection.

We found positive impacts of the FS initiative on our two measures of poverty. The two measures of poverty are specified as (1) consuming less than $1 per day per person and (2) consuming less than $2 per day per person. The impact was larger on the poorer group of households consuming less than $1 a day; the FS initiative reduced the fraction of households living below this threshold by 6 percentage points from a control group average of 75 percent. For the $2-a-day-measure of poverty, the impact was a reduction of 3 percentage points from the control group average of 93 percent.

One potential explanation for the positive economic benefits of the FS initiative and not the T&D lines is that poorer households were able to take advantage of the FS initiative relative to T&D lines. Our subgroup results (discussed below) suggest that the households affected by the FS initiative had somewhat lower baseline income than the households affected by T&D lines. It is possible that for these households affected by the FS initiative the economic benefits of getting access to electricity were more noticeable than for the households affected by T&D lines.

The FS initiative had no statistically significant impact on the remaining secondary measures of households' economic well-being. The outcomes include annual household income, per capita daily income, total household assets, and other indicators of assets and well-being (namely, electrifiable wall and roofing materials, number of rooms for sleeping, having a flush toilet, and having piped water). Even though the estimated impact on household assets is not statistically significant, it is a large negative value equal to about 57 percent of the control group mean.[63] In addition, it is almost statistically significant at the 10 percent level. The estimate primarily reflects the relatively small number of households with a negative asset total (that is, net liabilities)—only about 1.3 percent of the households have a negative asset total. When we eliminate cases with a negative asset total and take the log of assets, the estimated impact implies a change of about 2 percentage points in assets (that is, 0.02 on log assets) and is not statistically significant, with a *p*-value of 0.83. The implication is that the estimated negative impacts on total household assets are primarily a function of outliers.

[63] This estimate is statistically significant at the 10 percent level in the linear model without covariates.

Table VI.6. Estimated FS initiative impacts: Economic well-being

Follow-up outcome	Control mean	Impact	Standard error	*p*-value
Primary outcome				
Annual household nonelectricity consumption (TZS)	3,199,536	434,975	303,515	0.15
Secondary outcomes				
Annual household income (TZS)	2,800,947	422,508	651,737	0.52
Household per capita total daily consumption (TZS)	1,857	365	126***	0.00
Household per capita daily income (TZS)	1,557	381	365	0.33
Household consumes less than $1 per day per person	0.75	-0.06	0.02***	0.01
Household consumes less than $2 per day per person	0.93	-0.03	0.01***	0.01
Total household assets (TZS)	48,467,524	-27,418,966	17,234,278	0.10
Household lives in an electrifiable dwelling based on wall and roof materials	0.75	0.01	0.03	0.67
Average number of rooms in household for sleeping	3.73	-0.19	0.23	0.40
Household has a flush toilet	0.21	0.00	0.02	0.97
Household has piped water in rainy and dry seasons	0.06	-0.01	0.02	0.74

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

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 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 specific outcomes. Appendix E contains sample sizes for each outcome. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

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

7. Composition and mobility

We found no clear evidence of changes in community size but did find some evidence of a change in composition of the community attributable to the FS initiative (Table VI.7).

The FS initiative had no clear impact on the number of households living in the community. The initiative also had no clear impacts on any of the secondary outcomes covering rates of in- and out-migration, and rates of formation of new households (Tables VI.7). We also found no evidence of impacts on the secondary household outcomes as related to mobility within the community or selective out-migration per baseline income.

Table VI.7. Estimated FS initiative impacts: Composition and mobility

Follow-up outcome	Control mean	Impact	Standard error	p-value
Primary outcomes				
Number of households in community (based on household listing)[a]	253.16	-14.83	16.43	0.40
Secondary outcomes				
Fraction of households in community at follow-up that are in-migrants since 2011[a]	0.02	0.00	0.01	0.80
Fraction of households in community at follow-up that are newly formed since 2011[a]	0.01	0.00	0.00	0.33
Household moved within community since 2011[b]	0.09	0.03	0.02	0.12
Household out-migrated since 2011[b]	0.03	-0.01	0.01	0.59
Fraction of households that out-migrated since 2011 (of those with baseline income above district median)[b]	0.04	-0.02	0.02	0.35
Fraction of households that out-migrated since 2011 (of those with baseline income below district median)[b]	0.02	0.00	0.01	0.75

Source: Tanzania energy sector baseline and follow-up community, baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. Appendix E contains sample sizes for each outcome.

[a] This outcome is a community-level aggregate based on follow-up household listing data, which covers households in the subvillage where the household survey was conducted (but not other subvillages covered by the community survey). The analysis sample includes 178 communities, with 27 in the treatment group and 151 in the control group. Statistics on the first two secondary outcomes in this table are weighted by the number of in-migrant/newly formed households present at follow-up.

[b] This outcome is based on the follow-up household survey data. The analysis sample includes 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 specific outcomes. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

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

B. Findings for subgroups

In this section, we describe findings from the FS impact analysis for subgroups. The subgroups are defined by three baseline household characteristics—gender of the household head, age of the household head (younger than age 25 years; age 25 years or older), and the household's income quartile—and one baseline community characteristic, namely, the community's urban-rural status. Tables with estimated impacts for all subgroups appear in Appendix E.

1. Gender of household head at baseline

We did not find any statistically significant interactions between the gender of the head of household and the impacts of the FS initiative on our primary outcomes (Appendix Table E.3b).

Among male- and female-headed households, we found positive impacts on connection rates and the amount of electricity produced per month. However, the differentials in impacts between male- and female-headed households of 6 percentage points for connection rates and of 2.83 kWh for electricity produced were not statistically significant.

We did not find statistically significant differential impacts by gender of the household head on health outcomes for children and youth, even though the estimated impacts for each subgroup were consistent with the overall finding of increased health problems. We found no statistical difference between male- and female-headed households in the other primary outcomes we analyzed.

2. Age of household head at baseline

We did not find any statistically significant differences in impacts of the FS initiative by age of the household head (Appendix Table E.3c).

The FS initiative impacts on any of the primary outcomes were not statistically different between households with a head younger than age 25 and households with a head age 25 or older at baseline. The estimated impacts of the FS initiative on connection rates and monthly amounts of electricity consumed from any source were positive and are statistically significant only for households with an older head; they are not statistically significantly for those with a younger head. In part, the impacts related to age of household head reflect the fact that only 14 FS households were headed by an individual under age 25, suggesting that all findings in this section should be interpreted with caution.

3. Urban versus rural status at baseline

The FS initiative had a greater and positive impact on annual household nonelectricity consumption in the rural areas than in the urban areas (Appendix Table E.3d).

The FS initiative had no differential impacts by households' rural versus urban location on any of primary outcomes. The FS initiative increased annual household nonelectricity consumption in rural areas and decreased it urban areas, although only the result for rural areas was statistically significant at the 10 percent level. The positive impact on household nonelectricity consumption for rural households is substantially more positive (by over 850,000 TZS) than the estimated impact for urban households, but the differential is not statistically significant.

4. Baseline household income quartile

We found no evidence of differential FS initiative impacts across the income quartiles (Appendix Table E.3e).

The FS initiative impacts on any of the primary outcomes were not statistically different from each other across households in the four baseline income quartiles. We observed positive impacts of the FS initiative on connection rates in each income quartile, but the impacts were not statistically significantly different across the income quartiles. The same held for liquid fuel use per month as well as for youth and children's health problems, for which we found statistically significant impacts for some income quartiles; nonetheless, the impacts were not statistically different from the estimated impacts for other quartiles.

This page has been left blank for double-sided copying.

CHAPTER VII

IMPACTS OF ACTUALLY CONNECTING TO THE ELECTRIC GRID

This page has been left blank for double-sided copying.

Executive summary

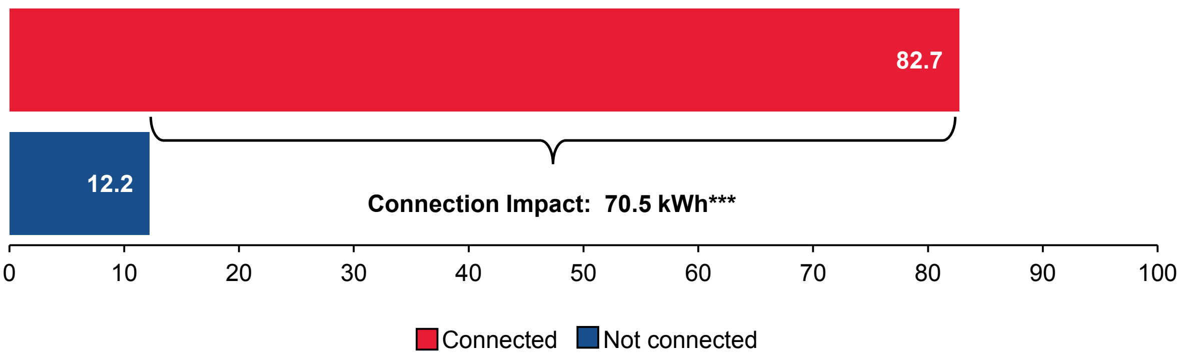
> **Impacts of actually connecting**
>
> - As expected, being connected increased consumption of electricity and use of electric appliances including lights.
> - It did not reduce use of liquid fuels.
> - It increased some education outcomes such as children studying at night by 12 minutes per day, but also increased TV watching by 73 minutes per day.
> - It did not improve health or safety outcomes but did increase access to family planning and HIV information electronically.
> - It had modest impacts on patterns of adult time use.
> - We found large and consistent positive impacts of connection to the grid on various measures of household economic well-being.

In previous chapters, we found that the estimated impact of line extensions on connection rates was much lower than expected. This limited the degree to which line extensions could directly affect other household outcomes. To explore potential impacts if connection rates increase in future, we present estimated impacts of actually connecting to the electric grid in Tanzania on five types of outcomes—(1) energy use, (2) education and child time use, (3) health and safety, (4) business and adult time use, and (5) economic well-being. These estimates are obtained using baseline and follow-up data collected as part of an energy sector project evaluation funded by MCC and implemented in a large number of rural and peri-urban communities. The data covered around 8,900 households in 358 communities. To estimate impacts we compare outcomes for households that were connected to the grid in 2015 with outcomes of similar households that did not connect. Almost all of the connected households connected after the baseline survey in 2011. Since we are using non-experimental methods the results should be viewed with some caution but may still be useful for estimating impacts of similar interventions that are found to increase connection rates but lack the rich data used here.

Energy use

Connection to the grid had, as expected, a large positive impact on the use of grid electricity while reducing the use of nongrid electricity. Connected households used about 82.7 kWh electricity per month from any source, which is about 70.5 kWh higher than usage among nonconnected households (Figure ES.VII.1). It also increased the use of electric appliances and the amount of light consumed and reduced households' expenses for mobile phone charging. Unexpectedly, it had no clear impact on liquid fuel use. It also had no clear impacts on solid fuel use.

Figure ES.VII.1. Impacts of being connected to grid on electricity use in kWh



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

Notes: This analysis sample includes 8,897 households, with 1,189 in the connected group and 7,629 in the not connected group. Impacts presented are regression-adjusted. Outcome is monthly amount of electricity used by household from any source in kilowatt hours (kWh).

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

Education and child time use

Connection to the grid had a small positive impact on children's enrollment in school. It also increased the time that children spent on studying at night by about 12 minutes per day. However, impacts on the time that children watched television were much larger at about 73 more minutes per day.

Health and safety

Being connected to the grid had no clear impacts on health outcomes. This may be related to the lack of clear impacts on liquid or solid fuel use. It also had no clear impacts on fires in the home but those were fairly infrequent in our data. It did, however increase the fractions of households that obtained family planning and HIV information electronically by around 10 percentage points each, compared with about 50 percent of non-connected households receiving each type of information electronically.

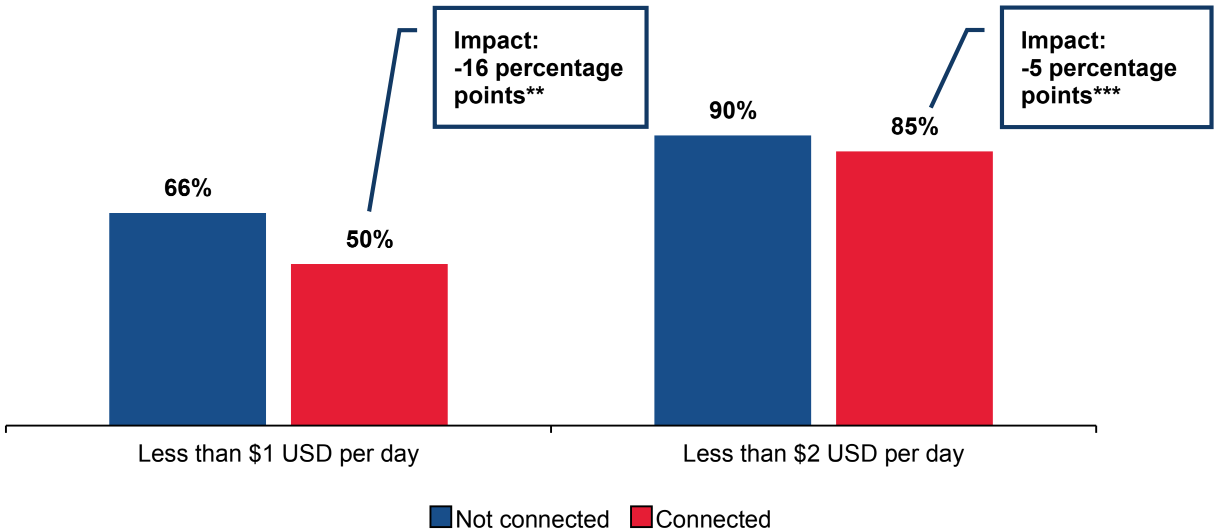
Business and adult time use

Connection to the grid had only modest impacts on patterns of time use among women and men (reducing time spent on collecting water and fuel but increasing time spent on socializing and resting, including watching television). At the same time being connected did increase the share of households operating an electrified IGA by 26 percentage points. It also led to a large increase in households' revenue from IGAs—58 to 83 percent higher revenue than among nonconnected households (depending on whether the measure was monthly or annual).

Economic well-being and composition and mobility

We found large and consistent positive impacts of connection to the grid on various measures of household economic well-being. Connection to the grid increased annual household nonelectric consumption by 27 percent, annual household income by 49 percent, per capita daily consumption by 24 percent, and per capita daily income by 26 percent. Impacts were not only found for well-off households as the results showed that being connected reduced the percent of households with per capita consumption less than $1 per day by 16 percentage points and the percent with less than $ 2 per day by 5 percentage points (Figure ES.VII.2).

Figure ES.VII.2. Impacts of being connected on per capita consumption below $1 and $2 per day



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

Notes: The analysis sample includes 8,897 households, with 1,189 in the connected group and 7,629 in the nonconnected group. Impacts presented are regression-adjusted.

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

Impacts by subgroup

Our subgroup analysis revealed some variation in impacts on a few outcomes, but not a distinctive pattern of impacts for any particular subgroup. We found, not surprisingly, that connection to the grid had greater impacts on the monthly amount of electricity consumed from any source among urban households than among rural households. We also found that connection to the grid had a larger impact on the likelihood of operating an IGA in households with a head younger than age 25 and in households in the lowest income quartile at baseline when compared with other households.

Introduction

In this chapter, we present our findings from the exploratory analysis of the impacts of connecting to the electric grid on household outcomes. We focus on household-level outcomes in five domains—(1) energy use, (2) education and child time use, (3) health and safety, (4) business and adult time use, and (5) economic well-being.[64] For connected households, outcomes in the energy use domain are the most proximal to being connected, and substantial differences are to be expected in the sources and amount of energy used by connected versus nonconnected households simply because the former households would use grid electricity. Connection to the grid may also open up business opportunities, create avenues for receiving and sharing information about market opportunities, enable household members to carry out work and other household activities after dark, and create opportunities to work for pay outside of home. These changes are likely to contribute to improvements in connected households' economic well-being. Connection to the grid can affect outcomes in the other domains by allowing children to study at night, by reducing indoor air pollution through a decrease in the use of certain types of fuels and thereby improving health outcomes, and by reducing the chances of fires caused by kerosene lamps in the home.

The connected households in the analysis were connected to the grid through both MCC and non-MCC lines. Our analytic sample includes non–Kigoma households in the T&D intervention and comparison communities that were in the baseline listing data and responded to the follow-up household survey. About 38 percent of the connected households connected to the grid through MCC-funded lines, another 41 percent connected through non-MCC lines built after 2011, and the remaining 21 percent connected through non-MCC lines built before 2011. However, regardless of the type of line, almost all of the connected households used in this analyses connected after the baseline survey in 2011.[65] On average, the connected households in the analysis had been connected to the grid for 2.23 years at the time of the follow-up household survey. Thus, the estimated impacts presented here reflect the impacts of connection to the electric grid for about 27 months, on average.

Our estimated impacts of actually connecting rely on the assumption that, conditional on the matching variables we used, households are connecting to the grid for reasons that would not affect their outcomes other than through being connected. This assumption would not seem reasonable if we were not able to control for a rich set of covariates describing household assets and income prior to the arrival of the new lines. However, conditional on that it is plausible that some households may have had stronger preferences for being connected than others—

[64] We dropped a number of variables where impacts were more likely due to being in a community with access to electricity rather than to the household being actually connected. These were: if the household had a child attending an electrified school, perceived safety, household whose last hospital visited had grid electricity at night, and if the household lived in an electrifiable dwelling based on wall and roof materials.

[65] All households included in the exploratory analysis were identified by community leaders as being not connected in 2011 when the listing data were collected to identify the baseline survey sample, but some later claimed that they were connected in 2011. More precisely, during the baseline survey in 2011, 49 households claimed that they were connected. These households may have connected between the time of the listing and the time of the survey. However, during the follow-up survey in 2015, there were 58 households claiming to have connected before 2011. Some of those households may have misremembered their connection date. Regardless, these households constitute less than 7 percent of our sample of households with grid connections at the time of the follow-up survey in 2015.

preferences that might not directly impact their other outcomes except through being connected. That said, given our reliance on a non-experimental design for this impact analysis, we are unable to rule out potential bias in the impact estimates, although additional analysis suggests no systematic bias. Nonetheless, the impact estimates derived from comparing connected households with matched nonconnected households may be biased because of unobserved differences in household characteristics that predict the choice to connect to the grid and are correlated with the untreated outcomes, conditional on the matching variables used. For example, random changes in household well-being since 2011 may predict both whether or not a household is connected and other outcomes, but we would be hard pressed to control directly for such changes in the analysis. Therefore, to assess potential bias in the estimated impacts, we conducted extensive checks of our model by (1) analyzing the balance between connected and matched nonconnected households on baseline characteristics, including a large set of variables not used as controls (Appendix A), and (2) by estimating IV models (Appendix H). We find no clear evidence of bias based on either set of checks, though as noted in Chapter III, the IV models are estimating impacts only for a subset of the sample (those whose decision to get connected is affected by the IVs). If impacts differ for that subset in ways that offset the bias, then the IV test for bias could be misleading. However, we have no reason to believe this had happened in the context of this analysis.

We also present the results of the within-study comparison designed to estimate the benefits of some key features of a non-experimental design in the context of this evaluation—controlling for a pretest (that is, the pre-program value of the outcome), using rich covariates, and performing local matching. The results suggest that these features are important in helping to reduce bias, further supporting the validity of the exploratory results presented in this chapter.

As in the previous chapters, we organize our discussion of impacts by domain and, within each domain, describe findings for our primary outcomes followed by discussions of secondary outcomes. Detailed definitions of these outcomes are presented in Appendix C.

A. Main findings

1. Energy use

Connection to the grid had, as expected, a large positive impact on the use of grid electricity while reducing the use of nongrid electricity; it also increased the use of electric appliances and the amount of light consumed and reduced households' expenses for mobile phone charging. Unexpectedly, it had no clear impact on liquid fuel use (Table VII.1).

Connection to the grid substantially increased households' use of electricity but had no clear impact on the use of liquid fuels. Connected households used about 82.7 kWh electricity per month from any source, which is about 70.5 kWh higher than usage among nonconnected households (nearly six times higher relative to nonconnected households); the estimated impact is statistically significant at the 1 percent level. Connection to the grid had no statistically significant impact on the amount of total liquid fuel (kerosene, diesel/gasoline, LPG) used per month, but it did reduce the amount of kerosene used by 1.37 liters per month (for a relative reduction of 60 percent).[66] We found that the reduction in kerosene use was primarily a function of a reduction in the hours that households used a kerosene lantern, although connection to the grid had no clear impact on the use of kerosene stoves for cooking. We also found no clear evidence of impact of connection on solid fuel use, which may also be reflective of no change in fuel used for cooking.

As for the source of electricity, connected households in the study communities, as opposed to nonconnected households, consumed about 83.8 more kWh electricity per month from grid electricity and about 9 fewer kWh per month in nongrid electricity. We examined the several components comprising our measure of electricity consumption, including flashlight use, kerosene lamp ownership and use, light bulb use, dry cell battery use, and car battery use. Connection to the grid increased the number of hours of light bulb use and reduced the use of flashlights, car batteries, dry cell batteries, and kerosene lamps (results not shown). It also resulted in a small reduction in the share of households owning a kerosene lamp but had no clear effect on the number of kerosene lamps owned, suggesting that households may tend to keep kerosene lamps as a backup (results not shown). Connection to the grid also reduced the share of households owning a generator by 14 percentage points (for a relative reduction of 39 percent), the share of households using dry cell batteries for fuel by 20 percentage points (a relative reduction of 36 percent), and the monthly hours of car battery use by 12.05 hours (from a comparison mean of 14.05 hours). These impacts combined likely explain much of the reduced consumption of nongrid electricity. The reduction in generator ownership might seem somewhat surprising given that the grid electricity supply may not be very reliable. However, it does seem consistent with the fact that the vast majority of households in our sample were very low-income. Households that did not have a generator at baseline may have been less able to afford one after paying the connection fee. Some of those that already had generators may have opted to sell theirs in order to pay that fee.

Connected households consumed more light and used more electrical appliances than nonconnected households. Households connected to the grid consumed about five times more light (about 963,000 more lumen-hours) without spending any more money on light than households not connected to the grid.[67] In addition, connection to the grid nearly tripled the number of electric appliances used by households—to 11.7 from a nonconnected group mean of about 3.8. One observation related to the impact of grid connection on the use of electric appliances is that 78 percent of connected households owned a television compared with 22 percent of nonconnected households; the impact of 56 percentage points is statistically significant at the 1 percent level. Connection to the grid also more than quadrupled the monthly hours of electric appliance use to 2,021 hours from a nonconnected group mean of 439 hours.

[66] A potential explanation for this result is that connected households used their extra income to consume more non-kerosene liquid fuels, like LPG, when their homes became electrified, relative to not connected households.

[67] For a few variables, such as the total monthly cost of light consumed by a household, the estimated impacts suggest that the connected group means are slightly negative. These are regression-adjusted estimates and reflect model predictions that result in negative predicted means for the connected group. In general, this does not mean that the actual values of these variables can be negative for the connected group; for most variables, the actual values are always positive or zero in our data. Only assets can be negative. Similarly, in some cases, the predicted mean of a binary variable for the connected group may be slightly over one.

Finally, connection to the grid increased households' ownership of mobile phones and reduced the expense for recharging these phones. Even though a vast majority (93 percent) of nonconnected households owned a mobile phone, connection to the grid increased the share of households with a mobile phone by 4 percentage points. At the same time, connected households saved money by charging mobile phones with grid electricity at home—about 3,156 TZS per month, which is about the entirety of what a nonconnected household spent per month for recharging its mobile phones.

Table VII.1. Estimated impacts of connection on energy use

Follow-up outcome	Not-connected mean	Impact	Standard error	*p*-value
Primary outcomes				
Monthly amount of electricity used by household from any source (kWh)	12.22	70.44	2.21***	0.00
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	9.35	2.95	4.17	0.48
Secondary outcomes				
Household uses electricity from any source except batteries	0.22	0.79	0.02***	0.00
Household owns a generator powered by liquid fuel/solar/hydro/wind	0.36	-0.14	0.02***	0.00
Monthly amount of				
Grid electricity used by household (kWh)	0.03	83.81	1.85***	0.00
Nongrid electricity used by household (kWh)	12.18	-9.04	1.58***	0.00
Kerosene used by household (liter)	2.27	-1.37	0.32***	0.00
Solid fuel used by household (kg)	138.35	-11.97	9.90	0.23
Number of electric tools/appliances owned by household	3.86	7.84	0.22***	0.00
Household owns a television	0.22	0.56	0.02***	0.00
Monthly hours of electric				
Tools/appliances used by household	439	1,582	46***	0.00
Fan used by household	0.54	13.87	2.02***	0.00
Monthly amount of light consumed by household (lumen-hours)	190,921	962,765	38,025***	0.00
Total monthly cost of light consumed by household (TZS)	12,960	-14,939	11,368	0.19
Household owns at least one mobile phone	0.93	0.04	0.01***	0.00
Monthly household costs for mobile phone recharge (TZS)	3,107	-3,156	208***	0.00

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

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 1,189 in the connected group and 7,629 in the nonconnected group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome.

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

2. Education and child time use

Connection to the grid increased the time children and youth spent studying and watching television while reducing time spent collecting water and fuel; it also had a small positive impact on school enrollment among children (Table VII.2).

We found positive impacts of connection to the grid on hours devoted to studying among children age 5 to 14 as well as among youth age 15 to 24. On average, connection to the grid increased the average total time per day children age 5 to 14 years spend studying by 0.23 hours (or about 14 minutes); the increase was primarily attributable to studying more hours at night as children spent about 12 more minutes studying at night. In addition, connection to the grid increased time spent studying at night for youth age 15 to 24 by 0.29 hours (or about 17 minutes), which, in turn, underpinned a 14-minute increase in the average total time per day spent by youth studying. All of these estimated impacts are statistically significant at the 1 percent level.

Connection to the grid also reduced time children spent collecting water and fuel but substantially increased their time spent watching television. Children in connected households spent 0.15 fewer hours (or 9 minutes) collecting water and fuel compared to children in nonconnected households (for a relative reduction of 21 percent). Connection to the grid did, however, increase the time that children spent on leisure/entertainment activities by 1.27 hours (for a relative increase of about 60 percent); nearly all of the increase was attributable to more time spent watching television—children in connected households spent 1.45 hours watching television in a day, which is six times more than children in nonconnected households.

Finally, connection to the grid had a positive impact on children's school enrollment. Connection to the grid increased by 2 percentage points the share of children age 5 to 14 enrolled in school relative to the enrollment rate of 83 percent among children in nonconnected households.

Table VII.2. Estimated impacts of connection on education and child time use

Follow-up outcome	Not-Connected mean	Impact	Standard error	p-value
Primary outcomes				
Average hours per day children (age 5 to 14) spend studying at night[a]	0.41	0.20	0.03***	0.00
Secondary outcome				
Average hours per day children (age 5 to 14) spend in total studying	0.71	0.23	0.04***	0.00
Average hours per day children (age 15 to 24) spend				
Studying at night	1.38	0.29	0.07***	0.00
In total studying	1.85	0.23	0.08***	0.01
Hours children (age 5 to 14) spent in last 24 hours[b]				
Collecting water and fuel	0.70	-0.15	0.04***	0.00
Performing other household chores	0.60	-0.06	0.03	0.10
On leisure/entertainment	2.11	1.27	0.12***	0.00
Watching television[c]	0.24	1.21	0.07***	0.00
Sleeping at night	9.12	0.05	0.04	0.26
Fraction of children age 5 to 14 in household attending a school	0.83	0.02	0.01*	0.06

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

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 1,189 in the connected group and 7,629 in the nonconnected group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome.

Parents were asked how many hours per day each child spends studying during the day and at night, and these numbers were averaged across all children of that age in the household. For other activities, parents were simply asked how much time one specific child age 5-14 spent on that activity during the past 24 hours.

[b] The next five outcomes are based on questions that were asked about only one child in each home.

[c] Time spent watching television is a component of the measure of time spent on leisure/entertainment.

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

3. Health and safety

Connection to the grid had no clear impact on health or safety outcomes though it did increase the fraction of households receiving health information through electronic means (Table VII.3).

Connection to the grid had no clear impact on two primary outcomes in the domain of health and safety—the share of children age 5 to 14 with health problems and the share of youth ages 15 to 24 with health problem in the seven days preceding the follow-up interview. It also had no clear impact on the fraction of households with a youth age 15 to 24 who missed work due to illness in the 30 days before the survey. Our measure of health focuses on vision problems, headaches, and respiratory problems—conditions that may be affected in the medium term by improved access to electricity. Connection to the grid did not have clear effects on the measures of internal or external pollution. This is consistent with the lack of clear impacts on liquid and solid fuel use and the lack of clear impacts on health outcomes.

Connection to the grid increased the fraction of households that received health information from electronic media. Connected households were 10 percentage points more likely than nonconnected households to receive information about family planning and about HIV from television, radio, the internet, or telephone; the estimated impacts on these two variables are both statistically significant at the 1 percent level. However, being connected had no clear impact on respondents' use of family planning.

Finally, both connected and nonconnected households faced an equal and very small risk of a major fire at home. Even though connection to the grid appeared to increase the risk of fire from electric sources by a very small margin, the estimate is statistically significant only at the 10 percent level and reflected the fact that only a minimal number of households in our data experienced a fire. The risk of fire from electric sources might have been offset by the reduction in the risk of nonelectric fires (the estimated impact on the latter is not statistically significant, but the magnitude of the reduction is much greater than the increased risk of electric fire).

Table VII.3. Estimated impacts of connection on health and safety

Follow-up outcome	Not-connected mean	Impact	Standard error	*p*-value
Primary outcomes				
Fraction of youth age 15 to 24 in the household with health problems in last 7 days[a]	0.24	0.00	0.02	0.86
Fraction of children age 5 to 14 in the household with health problems in last 7 days[a]	0.28	0.02	0.01	0.14
Secondary outcomes				
Household has a member age 15 to 24 who missed work in the last 30 days due to illness	0.18	-0.02	0.02	0.31
Monthly amount of internal pollution from soot (grams of black carbon)	165.21	20.30	31.27	0.52
Monthly amount of external pollution from carbon (kg CO2)	275.52	-3.33	19.29	0.86
Household received family planning information from television/radio/internet/telephone in last 30 days	0.52	0.10	0.02***	0.00
Household survey respondent currently using family planning method	0.38	-0.03	0.02	0.12
Household received HIV information from television/radio/internet/telephone in last 30 days	0.51	0.10	0.02***	0.00
Household had				
A major fire in home since 2011	0.03	0.00	0.01	0.49
A fire caused by electric source since 2011	0.0001	0.003	0.00*	0.06
A fire caused by nonelectric source since 2011	0.03	-0.01	0.01	0.20

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

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 1,189 in the connected group and 7,629 in the nonconnected group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome.

[a] Health problems include headaches; vision and respiratory problems.

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

4. Business and adult time use

Connection to the grid had no clear impact on involvement in an IGA, but it did increase the share of households operating an electrified IGA and increased their IGA revenues; it had mixed impacts on women's and men's patterns of time use (Table VII.4).

Connection to the grid did not have a clear effect on whether a household operated an IGA (the primary outcome of the domain), but it had a positive impact on whether an IGA was electrified as well as on the revenue associated with an IGA. Connection to the grid nearly tripled the share of households operating an electrically powered IGA to 26 percent of connected households, which is about 17 percentage points higher than that for nonconnected households. In addition, compared to nonconnected households, connected households earned between 58 and 83 percent higher revenue from their IGAs (depending on use of a monthly or annual measure of IGA revenue). The increase in revenue could represent a substantial improvement in the livelihood of connected households if the increase translated into a growth in profits.

The impact of connection to the grid on women's and men's patterns of time use was mixed. Despite the sizeable impact of electricity connection on households' IGA revenue, connection to the grid did not have clear effects on the amount of time women and men spent on wage labor, other income-generating activities, or nonwage labor. It reduced the amount of time that women and men spent collecting water and fuel (by 0.26 and 0.09 hours, respectively) and that men spent cooking, processing, or preparing food (by 0.08 hours) while increasing women's and men's time socializing and resting, primarily through increased time spent watching television (1.15 and 1.18 hours, respectively). It also increased the time men spent reading and studying (by 0.05 hours). We did not observe any clear impacts for women or men on other household chores and child care, or sleep at night.

Table VII.4. Estimated impacts of connection on business and adult time use

Follow-up outcome	Not-connected mean	Impact	Standard error	*p*-value
Primary outcomes				
Household operates any IGA	0.71	0.02	0.02	0.13
Secondary outcomes				
Household operates an IGA that uses grid electricity	0.09	0.17	0.02***	0.00
Household's monthly revenue from IGA (TZS)	213,962	124,272	42,759***	0.00
Household's annual revenue from IGA (TZS)	2,016,636	1,677,484	621,977***	0.01
Household has least one member who is a paid employee	0.25	0.02	0.02	0.15
Women's time use: Hours per day on each type of activity				
Wage labor (agricultural and nonagricultural)	0.92	0.10	0.10	0.34
Nonwage labor/other productive activities (farming and other activities)	0.85	-0.02	0.07	0.73
Other IGAs	1.55	0.00	0.13	0.99
Household chores and child care	2.46	0.02	0.08	0.76
Collecting fuel and water	1.12	-0.26	0.05***	0.00
Cooking, processing, and preparing food	3.39	-0.10	0.07	0.16
Reading and studying	0.05	0.02	0.02	0.39
Socializing and resting	4.64	1.21	0.10***	0.00
Time spent at home with family[a]	2.15	0.10	0.05	0.21
Watching television[a]	0.21	1.15	0.05***	0.00
Sleep at night	8.51	-0.01	0.04	0.75
Men's time use: Hours per day on each type of activity				
Wage labor (agricultural and nonagricultural)	1.91	-0.13	0.17	0.44
Nonwage labor/other productive activities (farming and other activities)	1.31	-0.14	0.11	0.21
Other IGAs	2.08	-0.04	0.16	0.82
Household chores and child care	0.44	-0.04	0.04	0.29
Collecting fuel and water	0.39	-0.10	0.04**	0.02
Cooking, processing, and preparing food	0.27	-0.08	0.03***	0.01
Reading and studying	0.11	0.05	0.03*	0.10
Socializing and resting	5.77	1.08	0.16***	0.00
Time spent at home with family[a]	1.90	0.11	0.07	0.13
Watching television[a]	0.34	1.18	0.07***	0.00
Sleep at night	8.35	-0.05	0.05	0.35

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

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 1,189 in the connected group and 7,629 in the nonconnected group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome.

[a] Time spent at home with family and watching television are components of the measure of time spent on socializing and resting.

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

5. Economic well-being

Connection to the grid substantially improved household consumption and income and reduced one poverty measure ($1-a-day per capita consumption) measure by 16 percentage points (Table VII.5).

Connection to the grid increased total household nonelectricity consumption in the year preceding the survey—the primary outcome in the domain of economic well-being. On average, connection to the grid increased annual household consumption by about 27 percent (to 5.28 million TZS); the estimated impact is statistically significant at the 1 percent level.

There is an apparent discrepancy between our finding that both T&D lines and the FS initiative appear to increase connection rates but not annual nonelectric consumption while being connected does appear to increase annual nonelectric consumption. The main reason for this apparent discrepancy is that the impacts of T&D lines and the FS initiative on connection rates are fairly small—at 10 and 13 percentage points respectively. Thus, the implied impacts on annual consumption are also likely to be small. In addition, the estimated impacts of T&D lines and the FS initiative on annual consumption are very imprecisely estimated. In combination this means that we cannot reject the hypothesis that the T&D lines and FS initiative results are consistent with the estimated impacts of connecting on annual consumption that we obtained from the exploratory analyses. We also checked nine other outcomes for apparent discrepancies of this type and found evidence of only 2 statistically significant differences out of the 20 differences we checked.[68]

The positive impact of connection to the grid on annual household consumption was echoed by strong positive impacts on various other measures of economic well-being and poverty. Compared to nonconnected households, connected households saw an increase in annual household income of 49 percent (to a little under 6 million TZS), per capita daily consumption of 23 percent, and per capita daily income of 26 percent. Being connected also decreased the fractions of households consuming less than $1 and $2 per capita per day by 16 percentage points (from a mean of 66 percent among not-connected households) and 5 percentage points (from a mean of 90 percent among not-connected households) respectively.

Although the point estimate was positive and large for total household assets, it was not significant; however, the evidence offers encouragement for other indicators of assets and well-being. Connection to the grid had a small positive impact on the average number of rooms for sleeping. It also increased the share of households with a flush toilet by 22 percentage points and households with piped water in both the rainy and dry seasons by 7 percentage points (for a relative increase of about 75 percent for each). Although it is possible that the changes reflect underlying unobserved differences between households in terms of their connection status, our models included baseline values for these infrastructure measures. The positive impacts on

[68] We compared the estimated impacts based on the T&D and FS analyses separately with the results based on the exploratory analysis of the primary outcomes in each domain by using T&D and FS status separately as instrumental variables and the Hausman statistical tests described in Appendix H. This allows for correlated impact estimates (results not shown). The statistically significant discrepancies found were for the estimated impact of T&D on amount of electricity used from any source, and the hours children age 5 to 14 spent on studying at night.

indicators of household infrastructure suggest that connection to the grid offers the potential for longer-term impacts on household assets.

Table VII.5. Estimated impacts of connection on economic well-being

Follow-up outcome	Not-connected mean	Impact	Standard error	*p*-value
Primary outcomes				
Annual household nonelectricity consumption (TZS)	4,158,205	1,124,708	200,123***	0.00
Secondary outcomes				
Annual household income (TZS)	4,026,342	1,967,360	782,533**	0.01
Household per capita daily consumption (TZS)	2,370	564	104***	0.00
Household per capita daily income (TZS)	2,400	633	352*	0.07
Household consumes less than $1 per day per person	0.66	-0.16	0.02***	0.00
Household consumes less than $2 per day per person	0.90	-0.05	0.01***	0.00
Total household assets (TZS)	61,659,737	21,935,112	57,891,313	0.70
Average number of rooms in household for sleeping	3.91	0.06	0.01***	0.00
Household has flush toilet	0.29	0.22	0.02***	0.00
Household has piped water in rainy and dry seasons	0.09	0.07	0.02***	0.00

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

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 1,189 in the connected group and 7,629 in the nonconnected group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. Appendix E contains sample sizes for each outcome.

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

B. Findings for subgroups

1. Gender of household head at baseline

In terms of primary outcomes, we found no statistically significant interactions between the gender of the household head and the impacts of connection to the grid (Appendix Table E.4b). Among male- and female-headed households, we found positive impacts of connection to the grid on the amount of electricity consumed per month, the time that children age 5 to 14 spent studying at night, and households' total nonelectricity consumption. However, the differential impact between male- and female-headed households is not statistically significant for any of these outcomes. We did not find statistically significant impacts of connection to the grid for either male- or female-headed households on any of the other primary outcomes, and the differential impacts are not statistically significant. Similarly, none of the estimated gender differences in impacts is statistically significant at the 5 percent level for T&D lines or the FS initiative.

2. Age of household head at baseline

Connection to the grid had a larger impact on a households' likelihood of operating an IGA among households with a head younger than age 25 than among households with an older head (Appendix Table E.4c). For the subgroup with a household head younger than age 25, connection to the grid had a larger positive impact on the fraction of households operating an IGA than households with an older head. The impact differential was 18 percentage points and was statistically significant at the 5 percent level. The differential impacts between the age subgroups were not statistically significant for any of the other primary outcomes. We found no consistent patterns in the impacts of T&D lines, the FS initiative, and connection to the grid by the household head's age.

3. Urban versus rural communities at baseline

Connection to the grid had a greater impact on the monthly amount of electricity consumed from any source by urban versus rural households but had no differential impact on other primary outcomes (Appendix Table E.4d). For both urban and rural households, connection to the grid had statistically significant positive impacts on the monthly amount of electricity consumed from any source, on the time that children age 5 to 14 study at night and in total, and on households' annual nonelectricity consumption; however, the impact differential between urban and rural households was statistically significant only for electricity consumed per month. Connection had a statistically significant positive impact on the share of households operating any IGA for rural households, but the impact was significant only at the 10 percent level and not statistically different from that for urban households. Connection also led to a statistically significant decrease in liquid fuel use in urban households, although this was significant only at the 10 percent level and was not significant for rural households. We also found some statistically significant differences in the impacts of T&D lines and the FS initiative by urban location, but with no consistent patterns.

4. Quartiles of baseline household income at baseline

We found no evidence of differential impacts of connection to the grid across the income quartiles except for impacts on the share of households operating any IGA; connection to the grid had larger impacts on the share of households operating any IGA among households in the lowest income quartile (Appendix Table E.4e). Connection to the grid had positive impacts on the share of households operating an IGA in the lowest income quartile, and the impacts across the income quartiles were jointly significantly different from each other. The estimated impacts across the income quartiles were not statistically significant for any of the other primary outcomes, even though we found statistically significant positive impacts of connection on time that children age 5 to 14 spent on studying at night and households' annual nonelectricity consumption for households in all income subgroups. As with other subgroup results, we found no patterns of consistent results by baseline income when examining impacts of T&D lines, the FS initiative, and connection to the grid.

C. Robustness of exploratory impacts of connection: Instrumental variables approach

As described in Chapter IV, the non-experimental approach we used to estimate impacts of connection to the grid involved the use of propensity score matching weights to match nonconnected households with connected households. All the diagnostics based on the characteristics included in the model, in combination with a larger set of baseline characteristics and outcomes, suggest that the matching made the nonconnected group statistically equivalent to connected households (Appendix A includes a discussion of our model diagnostics). We conducted an additional analysis (Section D of this chapter) that further supports our confidence in the non-experimental approach we used for estimating the impacts of connection. However, the non-experimental approach does not eliminate the chances, even if small, of underlying unobserved differences between the connected and nonconnected households that could account solely for observed differences; consequently, we cannot completely rule out the possibility of bias in the estimated impacts from the explanatory analysis. For example, it is possible that many unobserved changes in household circumstances that occurred between the baseline and follow-up surveys increased both observed income and connection rates. We would not expect such changes to bias our estimated impacts of the T&D lines or FS initiative, although the changes might bias the estimates of the impacts of connection to the grid.

To address the possibility of bias in the impacts of connection estimated by using the matching approach, we conducted the impact analysis by using a set of IVs. The IVs are a set of factors that affect household outcomes (such as energy use, or consumption) only by influencing the probability of connecting to the grid. We used the randomly assigned FS treatment status alone as an IV and in combination with whether the household was located within 30 meters of the nearest electric pole (controlling for distance to that pole). We also estimated models by adding in the interaction of the two factors—FS treatment status and if within 30 meters—as IVs.

For the study households, both factors influenced the households' likelihood of connecting to the grid, conditional on the other covariates in the models.[69] Moreover, given that the FS treatment was assigned through a lottery, the baseline households had no control over which households did and did not receive the low-cost connection offer However, for households that would have connected in the absence of FS it is effectively a onetime cash payment equal to the connection fee subsidy. For this reason it was important to also have the alternative instrument (based on distance to the pole) to check the sensitivity of our results.

[69] With use of the IV method, researchers are generally advised to use only instruments that are strong predictors of the endogenous variable—in our case, the connection rates. Experts generally recommend an F-statistic of at least 10 (Staiger and Stock 1997). When we estimate impacts by using only FS treatment status as an instrument, we calculate F-statistics between 13 and 26. When we add additional instruments, we calculate F-statistics from 35 to 79.

Location within 30 meters of a pole had the potential to be exogenous to the household because it was affected by (1) the decisions of engineers about where to place poles and (2) a TANESCO requirement for additional pole(s) for connecting to the grid if a house was located more than approximately 30 meters away.[70] As noted above, after controlling for distance to the pole, the indicator for being within 30 meters has the potential to be a valid IV. For example, even if engineers made a point of building lines through areas that are relatively densely populated (which seems likely), it was unlikely that they would make an effort to install lines exactly 30 meters away from a place where income levels change suddenly. Indeed, there may be few such locations in most communities.[71] Similarly, while some households may choose to move to be within 30 meters of a line, there could be a number of semi-random factors that affect these decisions, such as whether or not the household already owned property and/or a building that was within 30 meters of a line. In summary, these two factors had the potential to meet the requirements for strong and valid IVs. We discuss the potential weaknesses of the instruments in more detail in Appendix H. In particular, as discussed earlier, the IV analysis estimates impacts for a subset of the population. If the impacts differ for that subset in ways that offset the bias, then the IV results may be misleading, but we have no reasons for believing that this would be the case in the context of this analysis.

The findings from the IV approach provide no clear evidence of bias in the estimated impacts obtained using the matching approach. We estimate impacts for 10 outcomes—seven primary outcomes from five domains, and three key secondary outcomes from the domain of economic well-being. We compared the results by using Hausman tests, which are designed to compare more efficient estimates, such as those from our matched comparison analyses, with less efficient ones, such as those from our IV analyses (Nakamura and Nakamura 1981). The estimated impacts from the IV approach were generally not statistically different from the corresponding estimate from the matching approach. As shown in Appendix H, this conclusion holds for almost all models we analyzed. We estimated impacts of being connected using six variants of the IV analysis for each outcome. Only 3 of the 60 differentials from the main exploratory impact estimates across the 10 outcomes were statistically significant at the 5 percent level (Appendix H). In Table VII.6, we present results comparing our matched comparison results with results from the preferred IV model (referred to as M6 in Appendix H). Altogether, the evidence suggests that estimates from the IVs and exploratory matching analysis were statistically similar. A lack of evidence of statistically significant differences does not completely rule out the possibility of bias in the estimates from the main exploratory analysis, but it does offer some reassurance that the exploratory results are reasonable. In Appendix H, we provide further details on the IV analysis and the test statistics for the difference between the impact estimates from the matching and the IV approach.

[70] Distance to the line might be correlated with distance to a road which could have independent impacts on household outcomes. However, it is not clear why there would be a discontinuous jump in outcomes at the 30 meter cut-off if distance from the road was driving the results.

[71] A related concern is that households can pay for the installation of additional poles. Our understanding is that very few households can afford to do so.

Table VII.6. Impact of connection: Matched comparison analysis versus instrumental variable analysis

	Matched comparison analysis		FS status and 30–meter indicator as instrumental variables		
Household outcome	**Impact**	***p*-value**	**Impact**	***p*-value**	**DWH t-test statistic**
Amount of electricity used by household from any source (kWh)	70.44***	0.00	70.73***	0.00	-0.04
Amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	2.95	0.48	-7.44	0.82	0.33
Average hours per day children (age 5 to 14) spend on studying at night	0.20***	0.00	0.03	0.86	0.95
Fraction of youth age 15 to 24 in household with health problems (headaches; vision or respiratory problems) in last 7 days	0.00	0.86	0.13	0.18	-1.37
Fraction of children age 5 to 14 in household with health problems (headaches; vision or respiratory problems) in last 7 days	0.02	0.15	0.26**	0.01	-2.52
Household operates any IGA	0.02	0.14	-0.12	0.28	1.36
Annual household nonelectricity consumption (TZS)	1,124,708***	0.00	1,951,116**	0.04	-0.94
Household consumes less than $1 per day per person	-0.16***	0.00	-0.36***	0.00	1.84
Household consumes less than $2 per day per person	-0.05***	0.00	-0.12**	0.03	1.35
Annual household income (TZS)	1,967,360**	0.02	2,303,943	0.27	-0.18

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

Notes: The table shows regression-adjusted impact estimates from the matched comparison analysis presented earlier in this chapter and IV analysis with the indicators for FS treatment status and location 30 meters from an electric pole as instruments. The models are referred to as model M0 and M6, respectively, in Appendix H. The analysis sample includes 8,897 households in the matched comparison group analysis and 8,771 households in the IV analysis. For the matched comparison analysis, survey item nonresponse may have resulted in smaller sample sizes for specific outcomes; Appendix E contains sample sizes for each outcome.

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

D. Within-study comparison

In this section we present the results for our last research question: What types of non-experimental evaluation designs are best at producing impact estimates similar to an experimental design in the context of this evaluation?

To address this question, we performed a “within-study comparison” (WSC) analysis. A WSC typically involves a comparison of estimated impacts of an intervention obtained from a more rigorous design (in most cases an RCT) with the estimates from a non-experimental study after it has been adjusted to control for the biases that typically arise in a non-experiment. What is special about WSCs is that the two designs estimate impacts of the very same intervention in order to distinguish effects of the research designs from any differences in the programs analyzed in the experimental and non-experimental studies. The purpose of this WSC is to identify which non-experimental practices produce results similar to those from an experiment in order to provide empirical guidance to support the choice of a particular method when an experiment is not possible.

1. The logic of within-study comparisons

To estimate causal impacts of an intervention, we need to understand what the outcomes of the treated group would have been in the absence of the treatment – the so-called counterfactual (Imbens and Rubin 2015). Typically, this involves the identification or creation of a suitable comparison group whose outcomes are thought to be similar to those of the treatment group if the latter had not received treatment. RCTs, like the one we used to estimate the impacts of the low-cost connections initiative, are considered the gold standard for creating such a control group because, by design, the treatment and control groups are expected to be equivalent to each other in the absence of treatment.

For all non-experiments, existing statistical theory is not sufficiently specific to predict when studies will and will not result in unbiased estimates of causal relationships (Cook, Shadish, and Wong 2008). Statisticians invoke the crucial role of “strong ignorability” (Rosenbaum and Rubin 1983) but cannot say when such an assumption is met in real-world data. Likewise, econometricians sometimes invoke the crucial role of “instrumental variables” (Angrist and Krueger 2001; Angrist and Pischke 2009) but cannot say when specific cases meet the crucial “exclusion restriction” assumption except when the instrument is random assignment. It follows then that criteria other than theory alone are needed for judging the adequacy of the causal results claimed from non-experiments such as the one we used to estimate the impacts of the line extensions.

The within-study comparison, also called the design experiment, provides one empirical criterion for judging the adequacy of non-experiments. It tests the extent to which a non-experiment reproduces the same causal estimate as an experiment with which it shares the same treatment group. Within the social sciences, the within-study-comparison method first found application in the study of bias in non-experiments in job training in the United States as non-experiments generally failed to produce the same results as experiments (LaLonde, 1986; Fraker & Maynard, 1987). Since then, within-study comparisons have been carried out in many other social science fields, with much recent work suggesting more promise for non-experimental methods (e.g., Cook, Shadish, and Wong 2008).

Heckman and co-authors conducted several such studies and combined them with other methods, including simulations (Heckman, Ichimura, and Todd 1997, 1998; Heckman et al. 1998; Heckman and Hotz 1989), to conclude that the likelihood of achieving the experimental estimate increases as a function of combining three design elements—using local comparison groups, controlling for a pretest, and matching on additional rich covariates. Use of a local comparison group requires one or more geographically local non-experimental comparison observations for each treatment case. The rationale is that local groups control for more hidden, unmeasured influences as distant groups are more likely, for instance, to be subject to different local policies affecting the study outcome (Heckman, Ichimura, and Todd 1997). The second design element highlighted by Heckman et al.—controlling for a pretest—requires a pre-intervention measure of the post-test outcome measure; the rationale is that such a measure is likely to be correlated with the process of selection into treatment and is especially likely to be correlated with the study outcome (Heckman and Smith 1999). The authors' third design element—controlling for additional rich covariates—requires the use of a rich set of other covariates in addition to the pretest, with "rich" referring to the number of dimensions represented by the measured variables. The rationale is that the rich set of covariates offers a further control for hidden, unmeasured sources of bias (Imbens and Rubin 2015). There is no theoretical justification for the number of dimensions to cover or number of covariates to include in any given context—what matters is having the right covariates to obtain conditional independence of the outcome. However, lacking perfect knowledge about what those covariates are means that adding in more covariates may reduce the chances of obtaining biased estimates. In practice it is an empirical question whether or not that happens. Our data enable us to test that question in the context of this evaluation.

2. Design of the current within-study comparison

In the within-study comparisons conducted to date, each element (local comparison group, pretest, and rich covariates) sometimes did and sometimes did not reduce all of the bias in a non-experiment. Our within-study comparison analyzes whether combining all three elements provide a redundancy, a causal insurance, that none of them can guarantee by itself. The question has never been tested empirically in a direct fashion.

In order to estimate more models and avoid the uncertainty associated with the relatively small number of treated communities in the RCT, in the within study comparison we report we omit the treatment group data even though most within-study comparisons compare estimated impacts from the experimental treatment/control difference with the corresponding non-experimental difference, using the former as the causal benchmark. However, we used the control group from the RCT as the sole benchmark, they being initially identical to the treatment group in expectation. In this, we followed the approach of Bloom, Michalopoulos, and Hill (2005) and Heckman et al. (1998). These papers both compared outcomes between the control group from the experiment and the comparison group from the non-experiment to estimate bias, reasoning that if outcomes for these two groups were numerically equivalent then the treatment estimate for each would also be the same. This is because the treatment group is a common factor in the experimental and non-experimental estimates and so its effects cancel out. The within study comparison we present contrasts only the experimental control group and the non-experimental comparison, considering the experimental control group to be the best approximation to the true counterfactual.

We use this logic to examine the extent to which the non-equivalent comparison group comes to approximate the experimentally formed control group as a function of combining: (1) local versus distant comparison groups, (2) pretest measures of the study outcome that are or are not available, and (3) a rich set of other covariates that is or is not available. Given these two levels of each variable, eight combinations are created that allow us to estimate the extent to which bias is reduced by combining none of the three design elements, any one of them, any two of them, and then all three of them.

3. Specifics on implementing the within-study comparison

The WSC is designed to estimate impacts of the low-cost connections. For this reason, we selected the WSC comparison group from the line extensions comparison group to be similar to the low-cost connections control group in terms of new lines having been constructed in the community. In the control group about 90 percent of the households were in communities that had received new lines, with a similarly high percentage for the low-cost connections treatment group. In the line extensions comparison group only about 50 percent of households were in communities with new lines. To achieve balance on new lines we selected 76 line extensions communities for our WSC comparison group: all 59 line extensions comparison communities that got new lines and another 17 that did not. The latter group was randomly selected from all line extensions comparison communities without lines. This is the WSC comparison group that we use in the subsequent analysis and this group had about 90 percent of households in communities with new lines.

To test the importance of local comparison group, pretests, and rich covariates, we started with what we called the unadjusted model. This involved a simple comparison of outcomes from the RCT control group and the non-equivalent comparison group and estimates the size of the selection bias that needs to be adjusted away. Next, we implemented alternative models to estimate the extent to which the three design elements, singly and in all possible combinations, reduced the initial bias discovered. Table VII.7 provides an overview of the eight combinations referenced so that "L" indicates the presence of a local comparison group; "P" indicates that the outcome regressions control for a pre-intervention measure of the outcome under analysis; and "C" indicates that the analysis involved propensity score matching based on a rich set of covariates other than the pretest.

Table VII.7. Design element combinations analyzed

Combination	Local comparison group	Pretest	Rich set of covariates
None			
L	L		
P		P	
C			C
LP	L	P	
LC	L		C
PC		P	C
LPC	L	P	C

In the empirical analysis, we find that the bias was modest when averaged across all 59 outcomes analyzed even when using none of the design elements. This was because, first and as noted above, the WSC comparison group is a subset of the line extensions comparison group and the control group is a subset of the line extensions intervention group. The line extensions comparison communities were selected using a two-stage matching process to make them comparable to the line extensions intervention communities. Thus, similar balance might be expected for the control and WSC comparison groups. Second, we balanced on access to new lines between the control and the WSC comparison communities when creating the WSC comparison group.

On the other hand there are at least four reasons to expect a lack of balance between the control group and the WSC comparison group.

First, the initial matching for the line extensions evaluation at the community level did not succeed. In particular, we found a large difference in baseline community size based on the listing data, as discussed in Chapter IV (Table IV.4). This difference was possible in spite of the matching on community size from the community survey because of differences between the listing and survey data at baseline (Chapter IV). Other household-level covariates also differed before matching at the household level (Chaplin et al. 2015). Given that the control group is a subset of the line extensions intervention group and the WSC comparison group is a subset of the line extensions comparison group, we might expect similar differences in baseline characteristics between the control group and the WSC comparison group.

A second reason to expect lack of balance in our unadjusted WSC model is that this model does not adjust for the oversampling of small households in the control group.[72] Thus, the model did not take into account the fact that households identified as having two or fewer rooms were oversampled at baseline in the control group but not in the line extensions comparison group (Chapter IV). We use weights to adjust for this in the rest of this report but our unadjusted WSC model uses no weights.

The third reason to expect a lack of balance in our unadjusted WSC model is that the line extensions comparison group was selected to be balanced with the line extensions intervention group on baseline community characteristics (except for listing size, as discussed above). The control group is a random subset of the line extensions intervention group so should not change the balance. However, the WSC comparison group is a non-random subset of the line extensions comparison group. This non-random selection might also be expected to increase bias in the unadjusted model and, indeed, we did a comparison of the control group with the full line extensions comparison group and the resulting bias in the unadjusted model was about 25 percent smaller.

The final reason to expect a lack of balance in our unadjusted WSC model is that the control group communities were more likely to receive new lines under the MCC Compact, whereas the WSC comparison group communities were more likely to receive new lines through alternative channels. To the extent that the access to new lines funded by MCC might be qualitatively different than access via lines provided through alternative channels we would expect bias.

Our study investigated whether we can address these sources of bias through a combination of three different design factors that we need to describe in greater detail. The *local comparison group* was limited to households in the four closest comparison communities within a radius of 40 kilometers from the target control community. However, for 18 of the 151 control

[72] The WSC could in principle have used weights for the control group, but that would have eliminated one potential reason for different outcomes between the control and comparison group outcomes. It should also be noted that, even though the FS results presented in Chapter VI are based on weighted analyses, those estimates could have been made with unweighted data and still been a valid RCT, albeit for a different population (one with a higher fraction of households with two or fewer rooms).

communities, no comparison community was available within 40 kilometers.[73] In order not to lose these observations, we did not impose a distance restriction on these households when creating the local comparison group sample. [74]

To implement the *pretest* element, we controlled for the baseline value of the outcome in our outcome regressions. To implement *rich covariates*, we used a propensity score matching design at the household level that was designed to equate households within the control and comparison communities on the variables entering into the propensity score and on all those variables that were so similar initially that they did not need to be part of the propensity score. Matching was based on both community- and household-level baseline information excluding pretest measures of the study outcomes. Specifics on the propensity score matching method and technical details on the within-study comparison appear in Appendix G, and we controlled for the propensity score as a regressor in the outcome model.

These design elements take different approaches to addressing bias. The inclusion of a pretest (P) changes the outcome regression but does not change the composition of the comparison group. The local comparison group (L) and matching based on a rich set of additional covariates (C) both seek to attenuate bias by selecting a subset of comparison households that are most comparable to control households. In Table VII.8, we provide a brief overview of the composition of the comparison group for the different combinations of design elements. One important feature needs to be pointed out. When we selected a local comparison group without rich covariates (L and LP), we randomly selected households within local comparison communities. When we added rich covariates (CL and CLP), we implemented nearest-neighbor matching within these same communities.[75]

Table VII.8. Composition of comparison group by design element

Combination	Comparison group composition
None, P	All households in WSC comparison communities
L, LP	One randomly chosen household per control household, selected from the households in the up to four closest local WSC comparison communities
C, CP	One comparison household per control household, chosen through nearest-neighbor matching with replacement from among all WSC comparison households; selection based on propensity score estimated by using rich set of covariates
CL,CLP	One comparison household per control household, selected through nearest-neighbor matching with replacement from the households in the up to four closest local WSC comparison communities; selection based on propensity score estimated by using rich set of covariates

Notes: L = Local comparison group, P = Pre-test, and C = controlling for rich covariates.

[73] These 744 households make up about 18.83 percent of our analysis sample of 3,951 observations.

[74] This means that the match for these observations is identical to the match in the nonlocal approach.

[75] For the WSC, we implement nearest-neighbor matching and not the kernel matching procedure used in the remainder of the report. Kernel matching procedures are attractive from a mean squared error perspective as they have lower variance than nearest-neighbor matching. This lower variance, however, comes at the cost of additional expected bias (Stuart, 2010). In the WSC we are primarily concerned with the effectiveness for reducing bias and so we selected nearest-neighbor matching as our matching technique.

Let us now examine how these three design elements worked out in practice. The local comparison group method substantially reduced the distance for potential matches. The control communities were, on average, within 17.1 km of the 4 closest comparison communities. In contrast, the more distant comparison communities were, on average, about 52 km away from any control community. The average distance between households matched using the propensity score alone (i.e. not constrained to be local) was 367 km. However, when we limit the propensity score match to be local, that distance drops to 17.7 km. We can see here how controlling for rich community and household covariates together might additionally control for local factors such as weather, infrastructure, and common markets.

In the model without rich covariates, the control and comparison groups differed by 1.8 standard deviations of the comparison group propensity score. When we used the propensity score to match samples, the difference dropped to 0.23 standard deviations (see appendix Table G.7). Thus, matching on propensity scores substantially reduced the very large initial difference in scores.[76] By itself, local matching also substantially reduced the propensity score difference between the control and comparison groups. But it did so by about 60 percent (see appendix Table G.9) versus 85 percent in the propensity score analysis itself.[77]

Our bottom-line analysis compares the estimated difference between control and comparison groups from the unadjusted model with the same estimated difference from the models that included the different combinations of local matching, matching on just the pretest and matching on a rich set of community and household attributes. We defined the (standardized) bias as this estimated difference divided by the control group standard deviation and multiplied by the sign of the unadjusted estimate. The latter multiplication was important in that it permitted us to compare bias reduction across variables. We then averaged the bias across all 59 outcome variables studied in the low-cost connections RCT analysis for which a pretest measure was available. We analyzed average differences between the comparison and control groups rather than absolute or squared differences because the absolute or squared differences are influenced by noise factors, whereas noise should average to approximately zero when taking averages.[78] To be comprehensive, the analysis included all variables measuring primary and secondary outcomes with a baseline measurement included in the RCT analysis.

There were at least two alternatives to our method of assigning a sign to each variable. One would have involved the assignment to each variable of a sign based on the expected impact of the low-cost connections initiative. In most cases we did expect certain results—for example we expected low-cost connections to increase connection rates, consumption of electricity, and use of electric appliances. However, that expectation was ambiguous for several variables, such as time spent sleeping, and at least theoretically ambiguous for most. For example, the low-cost connections initiative could have decreased liquid fuel use to the extent that people used electricity to replace kerosene, but it could have increased liquid fuel use through an income

---

[76] It did not fully reduce the difference to zero, as comparison households were limited to be matched 9 times.

[77] We would expect a larger comparison group to have led to smaller remaining differences in propensity scores both for the propensity score match and the local match.

[78] An analysis of absolute or squared differences would be useful but would require a different estimation method in order to adjust for uncertainty in the estimates. Consequently we leave that as a topic for future research.

effect. The second alternative would have assigned signs based on whether a variable was "good" or "bad." Again, the result was ambiguous in several cases; for example, it was not clear if liquid fuel use is good because it provides consumption benefits or bad because it creates pollution relative to electricity. For these reasons, to assign signs, we used the differences in follow-up outcomes in the unadjusted model.

When conducting the within-study comparison, we did not try to replicate either the non-experimental methods used to estimate the impacts of the line extensions or the methods used to estimate the impacts of actually connecting to the grid that are presented earlier in this report.[79] However, the methods are conceptually similar in the sense that both of those methods adjusted for pre-tests and rich covariates. More precisely, we used propensity score matching at the household level; included both household- and community-level covariates to create the propensity scores; and used pretests (when available) and rich covariates. Local matching is implicitly used in the main analyses in the rest of the report. When estimating impacts of line extensions we did local matching in the sense that we matched on region. The comparison communities were selected so that the proportions by region were similar to the intervention group and region dummies were included as covariates in the propensity score. Similarly when estimating impacts of actually connecting we did some matching by community in the sense that most connected households could have been locally matched because they were in communities that contained at least some comparison households (that is, those that were not connected). In addition, the propensity score model included community characteristics. Hence, the results of the within-study comparison of the low-cost connections impact analysis are relevant to the non-experimental methods used in the rest of this evaluation.

4. Results

In Figure VII.1, we provide a graphic overview of the extent to which the non-experimental comparison groups were able to approximate the experimental control group, averaging results across all 59 outcomes. The vertical-axis shows the difference between the comparison and control groups, standardized by the control group follow-up standard deviation and averaged across the outcome measures. We present the difference for all eight design combinations. "None" indicates the unadjusted model in which no correction was used except the original matching on communities. "L" indicates that the comparison group was restricted to up to four communities within 40 kilometers.[80] "P" denotes the inclusion of a pretest measure, and "C" denotes the use of a rich set of covariates for individual matching. A perfect approximation occurs, on average, when there are no differences between the two groups so that a score of exactly zero is achieved. In practice, an exact score of zero is not to be expected, given sampling error in both the randomized control and nonrandomized comparison groups. No standard of

[79] This was done because we initially started the study as a blinded study, whereby the WSC and RCT teams were blinded to each other's results, and the WSC team made all its modeling decisions before seeing the outcome data. This initial analysis focused on four outcome variables and did not make use of the indicator measuring whether the community had received a new line since the baseline study. When outcomes were provided to the WSC team, the bias for the four variables in the unadjusted model was very small, leaving no room for improvement when implementing our three design elements.

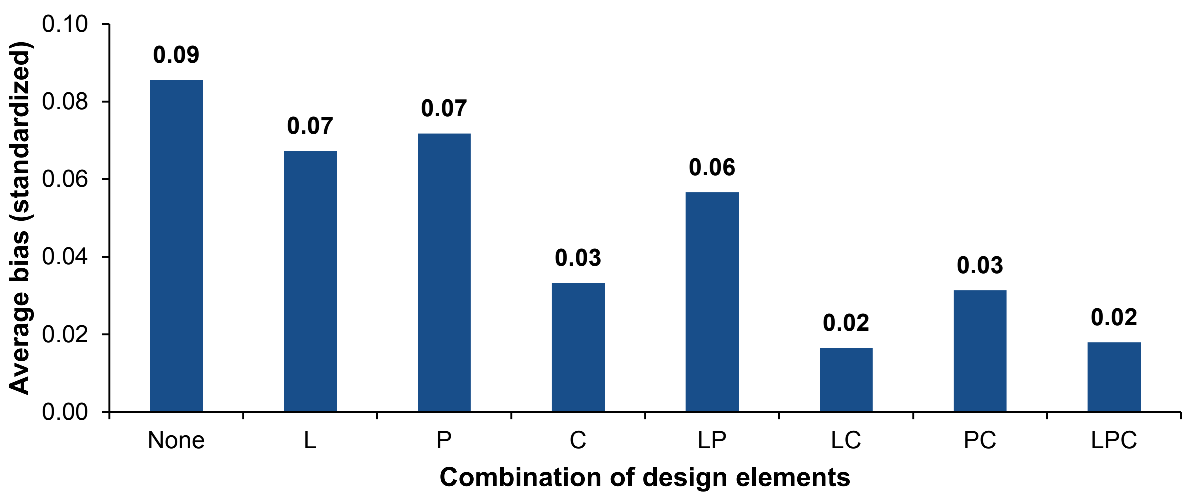
[80] When there was no comparison village within 40 kilometers, we allowed the comparison group to be any community beyond 40 kilometers in order to retain the observation.

acceptable group differences is universally accepted, though differences of 0.10 standard deviation units and less are sometimes considered acceptable.

The first column of Figure VII.1 shows that the initial selection bias averaged across all 59 outcomes is 0.086 standard deviations based on control group follow-up standard deviations). For example, the difference between the time that control and comparison women spent on fetching firewood was 13.6 minutes. This is relative to the control group mean and standard deviation of 89.3 and 97.6 minutes, respectively. The bias in the unadjusted model is thus 0.14 standard deviations. For the number of hours children spent on studying, the difference was 8.6 minutes relative to the control group mean and standard deviation of 37.4 and 49.8 minutes, respectively, which corresponds to a bias of 0.17 standard deviations.

While the average initial bias of 0.086 was only moderate in size, it was statistically significantly different from zero at the 1 percent level. Including any of the design effect combinations reduces this bias, especially when local matching occurs and is supplemented by the use of rich covariates —whether the pretest is included or not (Figure VII.1). In the middle column of Table VII.9, we provide the numeric results that underlie Figure VII.1. In the last column, we also present the results of tests of significance between the unadjusted outcome (indicated by "None") and the combinations of design elements.

Figure VII.1. Average bias by design element combination



Note: Figure VII.1 presents the average standardized difference between the control and the comparison group follow-up survey outcomes for eight combinations of the three design elements. The differences were standardized by the control group follow-up outcome standard deviation. The average was taken across all 59 outcome variables that were analyzed as primary and secondary outcomes as part of the RCT and for which a baseline measure was available. "L" indicates that a local comparison group was formed; "P" that the regressions controlled for a pre-intervention measure; and "C" that the analysis involved propensity score matching based on a rich set of covariates. The text describes the eight design control features in more detail.

Table VII.9. Average bias across 59 outcome variables

Combination of design elements	Average standardized bias	Difference in average standardized bias to base category
None	0.086*** (0.009)	Base category
L	0.067*** (0.009)	-0.018** (0.008)
P	0.072*** (0.008)	-0.014*** (0.003)
C	0.033*** (0.011)	-0.052*** (0.013)
LP	0.057*** (0.008)	-0.029*** (0.008)
LC	0.017* (0.009)	-0.069*** (0.013)
PC	0.031*** (0.011)	-0.054*** (0.012)
LPC	0.018* (0.009)	-0.068*** (0.013)

Note: Table VII.9 presents regression results using one observation for each combination of design elements with the 59 primary and secondary outcomes considered in the RCT analysis that had a pretest measure. Thus, there are a total of 472 observations. The middle column presents the standardized average bias under different combinations of design elements, where the standardized bias was averaged over the 59 variables. The variables were standardized by the standard deviation of the control group outcome. "None" indicates that a simple difference was taken between control and comparison groups. "L" indicates that a local comparison group was formed; "P" that the regressions controlled for a pre-intervention measure; and "C" that the analysis involved propensity score matching based on a rich set of covariates. The text describes the eight design control features in more detail. The last column shows the differences (and standard error of the differences) between the average bias in the unadjusted comparisons and the bias when design elements were included and including variable fixed effects for each of the 59 variables. Given that the bias across the different combinations of design elements was correlated, we use cluster-robust standard errors that allow the correlations between residuals to vary across design elements within variable. Standard errors are in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

All combinations of design elements reduced bias relative to the unadjusted outcome (Table VII.9, last column). Local matching with rich covariates seemed to perform particularly well. Even though the bias was not reduced to zero, it did decline by 80 percent, without including any control for the pretest in the outcome equation. Column 3 presents formal tests for the difference of the seven combinations of design elements relative to the base category, which is the simple unadjusted difference indicated by "None." We see that the reductions in bias are statistically significant for all combinations of design elements.[81]

[81] We note that some of the differences are more precisely measured than others. The reason is that use of the "C" and "L" design elements reduced sample sizes compared to the unadjusted model and the "P"-only model. The comparison group formed for "C" relied on only 31.6 percent of the comparison group used in the unadjusted and "P" models. The "C" model dropped observations in the comparison group that were poorly matched on the propensity score. The "L" model dropped observations in the comparison group that were not close enough to a control community. The comparison group formed for the "LC" and "LPC" design elements used only 23.1 percent of the entire comparison group.

In the appendix Table G.10, we also present tests for whether the difference between each pair of design elements is statistically significant.

As additional robustness checks, we also conducted two further analyses. First, we conducted the same analysis for the four outcome domains separately: energy use; education and child time use; business and adult time use; and economic well-being. We find that the combination of design elements typically reduce bias in similar ways across these four outcome domains. See Table G.11 for details.

Second, we use the 104 communities that did not have access to the electricity network at endline as potential matches for the control communities. We select this comparison group in order to investigate to what extent the combinations of design elements reduce bias when we start with a less-well matched group of comparison communities. We then observe greater initial selection bias but also substantial and statistically significant bias reduction from the three design elements when combined. See Table G.12 and the discussion in Appendix G for details.

Both sets of robustness checks are generally supportive of the conclusion that the combination of design elements provides some insurance against any of them not being effective. The bias reduction from using just one or two design elements is typically not meaningfully larger relative to the combination of three design elements. It is however sometimes substantially smaller.

To summarize, our results suggest that all three design elements were effective in reducing bias but that the use of local matching and controls for rich covariates in combination were most effective, with or without the use of pretests. One possible explanation for the apparently weak performance of pretests in removing bias in this situation is that many of the outcome variables related directly to electricity use had means close to 0 at baseline and thus little variation, but higher variation at follow-up—consequently, controlling for their baseline values may not have been as effective as it might be in other situations where baseline values of an outcome might vary more.

The bias reduction observed in this *methodological* study is an underestimate for the bias reduction we would anticipate in an actual study, for two reasons: First, in order to conceptually cleanly separate the value of the pre-test from the contribution of the rich covariates, we excluded *all* outcome variables (and highly related variables) from the set of rich covariates. For example, since the time-use variables “hours spent studying at night - children 5-14” and “hours spent collecting firewood and water - females” were part of the set of outcome variables, we dropped all time-use variables from the set of rich covariates. In an actual study, the set of rich covariates for the propensity score model would of course include these variables, leading to further potential for bias reduction.

Second, our local comparison group was selected among the available communities, the line extensions comparison communities. While the selection of line extensions comparison communities implicitly allowed for local matching through the inclusion of region dummies there was nothing that explicitly forced the matched communities to be within a certain radius of the control communities. This has two consequences, first in terms of bias and second in terms of variance. There were 18 control communities that did not have any local comparison communities within a radius of 40 kilometers. Since the local matching performed particularly well, it is plausible that matching these 18 communities locally could have also contributed to further bias reduction. Second, specifically selected local communities would lead to less variable impact estimates for individual covariates, as we would expect many more households to be matched as comparison households. Among the set of comparison households in this study, only 675 of the 2,919 households in the 76 comparison communities function as local matches for the 3,951 control households. With a larger sample of matches, we would anticipate less random variation and thus, a further bias reduction.

This page has been left blank for double-sided copying.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

This page has been left blank for double-sided copying.

Tanzania is a developing country with low income and one of the lowest rates of electrification in the world (World Bank 2016). In an effort to address the country's challenges related to poverty and economic growth, MCC allocated $207.2 million to MCA-T to implement an energy sector project under a compact with the government of Tanzania. MCA-T worked with MCC and TANESCO to implement the project. In this report we evaluate two components of the project—the distribution systems' rehabilitation and extension activity, also known as the transmission and distribution (T&D) activity; and a financing scheme (FS) initiative to facilitate lower-cost electricity connections to customers. We also conducted an exploratory analysis of the impacts of connecting to the electric grid. Guided by the conceptual framework for the Tanzania energy project, we examined outcomes in seven domains: (1) connection rates, (2) energy use, (3) education and child time use, (4) health and safety, (5) business activity and adult time use, (6) economic well-being, and (7) community composition and household mobility. Within each domain we specified a few outcomes as primary and a larger number as secondary. We used household level outcomes in these domains for the T&D lines, FS initiative, and exploratory analyses. For the T&D analysis, we also examined community-level outcomes. The evaluation focused on the part of the T&D activity that involved the construction of new distribution lines in over 300 communities spread throughout seven regions of Tanzania. The new lines were completed between October 2012 and December 2013. The FS initiative was offered to a randomly selected subset of 29 of these communities to address the concern that normal connection fees pose a barrier to electricity access for the majority of Tanzanian residents, particularly for the peri-urban and rural populations living where the T&D lines were built. The connection fee was normally 320,960 TZS in urban areas and 177,000 TZS in rural areas and the FS initiative reduced it to 30,000 TZS. We selected the FS treatment communities in July 2012, and FS implementation took place from February 2013 to June 2014, with 1,814 connections made under the FS initiative.

The evaluation used both community- and household-level data that were collected in 2011 (before construction of the new lines) and again in 2015, about 20 to 34 months after the T&D lines were ready for use and 14 to 24 months after completion of the FS initiative. The community-level data used to estimate impacts of line extensions covered 178 communities targeted to receive the new T&D lines and 182 carefully matched comparison communities in 6 of the 7 regions that got new lines.[82]. The household-level data came from a subset of households within the T&D communities that were somewhat more likely to get access to the new lines and from a subset of households in the comparison communities selected to be similar.

We used rigorous evaluation designs to estimate impacts of the T&D lines (Chapter V), of the FS initiative (Chapter VI), and of actually being connected to the grid (Chapter VII). To estimate impacts of the T&D lines, we compared outcomes for communities and households in the T&D intervention group that were expected to receive the MCC-funded lines with those in the matched comparison group that were not expected to receive MCC-funded lines. To estimate impacts of the FS initiative, we used a group randomized controlled evaluation design and compared household outcomes in the T&D intervention communities that were randomly selected to receive offers of low-cost connections to the grid with those of T&D intervention communities that did not receive the low-cost offers. To estimate impacts of actual connection to

[82] The seventh region (Kigoma) was excluded from most of our analyses because it was not identified as being part of this activity at the time of our baseline survey.

the grid, we compared outcomes for connected households with those for carefully matched nonconnected households.

In the rest of this chapter, we summarize the estimated impacts of the T&D lines, of the FS initiative, and of actually being connected to the grid based on our community- and household-level data. We also briefly describe the results of a within-study-comparison analysis that we performed to evaluate the benefits of different levels of rigor in our analyses. Finally, we conclude with a discussion of the findings' policy implications.

A. Impacts of T&D lines

Drawing on results from our household survey, we estimated that the T&D lines increased connection rates but achieved only about 31 percent of the number of connections assumed in an economic rate of return (ERR) calculation produced by MCC in 2008. The ERR was based on an estimate of 35,000 new connections in the year after the lines were built. In comparison, we estimated the completion of 10,794 new connections to MCC lines by the time of the follow-up survey in late 2015. Thus, we estimated that about 31 percent (10,794/35,000) of the goal has been achieved. Our estimate of the number of connections installed is based on data collected in late 2015, which is two to three years after the lines had been built, depending on the community. In contrast, the original assumption was for the first year after the lines were built. Thus, the original assumption was ambitious in terms of timing and is not supported in our data. Connection rates could increase over time and, as noted in our literature review, such increases are commonly found for other electricity line projects but it is difficult to know whether or not similar increases would be found for the communities receiving T&D lines.

Even though the number of connections originally assumed for the T&D lines were not reached, our data do suggest that the T&D lines had positive impacts on connection rates and access to grid electricity, defined as being located within 30 meters of a low-voltage electric pole. These results hold based on both community- and household-level measures. Using data collected from our household survey, we found that the T&D lines increased connection rates by about 10 percentage points from a comparison group base of about 11 percentage points. We also found that the T&D lines had much larger positive impacts on access than on connection rates. More precisely, we estimated that the T&D lines increased the fraction of households within 30 meters of an electric pole by about 20 percentage points, from a comparison group mean of 24 percentage points. This latter finding is important because it means that estimated impacts on access rates are at least double the estimated impacts on connection rates.[83] Thus, if all households with access to the new lines had connected, then MCC would have achieved about 60 percent of the total number of connections assumed. This would still leave it 40 percent short of that assumption. There are two ways in which the original target could still be reached. First, some households could purchase additional poles, though this would be quite costly. Second, households could relocate to be nearer to the new MCC lines. We found little evidence of in-migration in our survey data, but if in-migration increases substantially in future years, then MCC might achieve its original assumed number of connections.

[83] Households more than 30 meters from a pole usually have to pay a high cost for an additional pole. Hence, connection rates are much lower for those farther from the poles. Consequently, we defined access to the national grid as being located within 30 meters of an electric pole.

Even though the T&D lines increased connection and access rates, it had no clear impact on the overall amount of energy used by households. This seemingly puzzling result is at least partly explained by the substitution of grid electricity for nongrid electricity (from generators and car batteries). We estimated that the T&D lines reduced the use of nongrid electricity by 5.3 kWh (for a relative reduction of 58 percent) and the fraction of households owning a generator by 9 percentage points (for a relative reduction of 29 percent). The lower cost of grid electricity likely drove the substitution of grid electricity for nongrid electricity. It is also quite possible that non-grid electricity was used far less efficiently than electricity from the grid. For example, households may have used only a fraction of the electricity they produced with their generators but still had to pay for all of the fuel consumed. In contrast, they pay only for electricity used from the grid.

The T&D lines had positive impacts on a number of important intermediate outcomes related directly to electricity, such as using more electric tools and appliances, consuming more light, and spending less on recharging households' mobile phones. It also increased the fraction of communities with schools powered by electricity and the fractions of businesses and IGAs with electricity.

The increase in light consumed appears to be attributable to a substitution of electric lights for kerosene lights. We found no clear impact of the T&D lines on total kerosene consumption but the result was very imprecise; indeed the estimated impact suggested a 19 percent reduction relative to the comparison group. This indicates that the analysis lacked statistical power to detect precisely an impact as large as the one we observed.

The T&D lines had no perceptible impact on related outcomes such as the hours that children spent on studying, IGA income, or household income, but it increased the time that both adults and children spent on watching television.

We saw large positive impacts on perceived night-time safety associated with light and found no clearly positive impact on whether communities had an electrified health facility, even though less than a third of communities in the comparison group had such facilities.

Despite an absence of clear impacts on economic outcomes in general, our data suggest that the T&D lines increased the price of residential land, as reported by community survey respondents, by about 34 percent. Given that the community survey did not focus on land with direct access to electricity, the increase of 34 percent likely underestimated the effect of the T&D lines on property with direct access to the new lines. On the other hand, the household survey data did not demonstrate clearly positive impacts on total household assets.

We found no clear evidence of impacts of the T&D lines on the composition and mobility of the affected communities. This outcome could suggest a constraint on the potential for the newly built lines to be cost-effective as many were built in rural areas where relatively few people live.

We did see some differences in impacts of T&D lines by subgroup. We found some suggestive evidence of larger impacts on connection rates for male- versus female-headed households, but the difference is statistically significant only at the 10 percent level. We did find evidence of larger impacts on connection rates for households with a head age 25 years or older versus households with a head younger than age 25. The T&D lines appeared to reduce hours of studying more in urban areas than in rural areas but also to improve health outcomes more in urban rather than in rural areas. Finally, we found somewhat larger impacts on connection rates for higher-income households than for lower-income households.

The estimated impacts of line extensions incorporate both direct impacts of line extensions on the outcomes covered by our study and indirect impacts that are caused by related investments that were affected by the line extensions, such as efforts to improve schools, water supplies, health centers, and roads. They also incorporate the fact that about 15 percent of the communities targeted for line extensions also obtained low cost connections. As discussed in Chapter V we expect that the net effect of these indirect impacts may be relatively modest, but we have not tried to disentangle them in this report.

B. FS initiative impacts

The FS initiative had a 13 percentage point impact on connection rates as compared to a control group mean of 18 percentage points and an estimated impact of the T&D lines of 10 percentage points. The fact that the estimated impact of the FS initiative was similar in magnitude to the estimated impact of the T&D lines helps highlight the importance of connection costs as a barrier to the use of grid electricity in the study communities. Interestingly, we also estimated a 14 percentage point impact of the FS initiative on a household's location within 30 meters of a pole, suggesting either that households moved to be closer to the poles or that the poles in the FS initiative communities were built to be closer to homes than in the control communities, perhaps because of knowledge, on part of the engineers, of the existence of the FS initiative. Such an outcome is possible because the firm building the lines needed access to land to install the poles and might have found it easier to gain needed access in communities expecting the FS initiative.

Like the T&D lines, the FS initiative had no clear impact on the use of liquid fuels or on kerosene use. In addition to the possible explanations mentioned above for the T&D lines results, it seems possible that households' increased consumption of kerosene in the FS initiative communities may partly reflect the purchase of more kerosene for nonlighting purposes than in the comparison communities, offsetting any reductions associated with a switch from kerosene to electric light.

Even though the T&D lines did not translate into a clear increase in the amount of electricity consumed, the FS initiative did so. It is possible that households connecting to the grid in response to the FS initiative were lower-income households, on average, than the households that connected in response to the T&D lines and, consequently, were less likely to have been consuming large amounts of electricity from generators.[84] Hence, the households affected by the FS initiative might have been more likely to see a net increase in total electricity consumed than the households affected by the T&D lines only.

[84] We have some evidence supporting this hypothesis. In particular, the estimated impacts of the T&D lines on connections were much larger for households with higher baseline income compared to those with lower baseline income. In contrast, the differentials in impact by income were much smaller for the FS initiative.

We found no evidence that the FS initiative increased children's hours spent on studying, but we did see increased time spent on watching television, similar to what we found for impacts of the T&D lines on the same outcomes. Children in FS communities watched about 11 minutes per day more television than children in non-FS communities.

Even though the T&D lines had no clear impacts on health outcomes, the FS initiative appears to have increased health problems for children and possibly even for adults by about 6 or 7 percentage points. These results are plausible in part because the FS initiative increased television watching but did not appear to reduce kerosene use or indoor pollution. Therefore, if increased television watching increased the amount of time spent indoors near polluting fuels, it could have worsened health outcomes. Health outcomes measured included having difficulty breathing; experiencing wheezing, coughing, sneezing, sore throat, nasal discharge, or congestion; and having problems with vision—all of which may be related to indoor air pollution. The estimated impacts on watching television were somewhat larger for the FS initiative (at 11 minutes per day) than for the T&D lines (at 7 minutes per day).

As was the case with the T&D lines, we saw large positive impacts of FS on perceived safety at night. Depending on the measure considered, the FS initiative increased perceived safety by between 5 and 16 percentage points, compared to the impacts on perceived safety of 6 and 20 percentage points attributable to the T&D lines. These impacts are sometimes even larger than the estimated impacts of T&D lines and the FS initiative on connection rates. 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 night-time light produced by increases in the share of connected households in the community.

Neither the T&D lines nor the FS initiative had clear impacts on households' annual nonelectricity consumption or annual income. However, we did see a positive estimated impact of the FS initiative on per capita daily consumption of 365 TZS as well as desirable negative impacts on poverty rates as measured by the fraction of households with consumption of less than $1 per day and less than $2 per day per capita; the rates decreased by 6 and 3 percentage points, respectively. Finally, as was the case with the T&D lines, we did not find clearly positive impacts of the FS initiative on total household assets—indeed, the point estimate is negative and almost statistically significant at the 10 percent level; however, the estimated negative impacts are primarily a function of outliers.

Evidence that FS reduces poverty but does not increase household income might seem puzzling. There are two possible explanations for this result. First, while the point estimates of FS impacts on income are not statistically significant, they are moderately large in size. Second, even though the interactions between FS and baseline income quartile on follow-up nonelectricity consumption are not statistically significant, the point estimates are largest for the subgroup with the second highest quartile of baseline income.[85] This group of households was between the 50th and 75th percentile on baseline income. About 75 percent of households are poor (earning less than $1 per day per capita) in the control group (see Table E.3a). This suggests

[85] We estimated subgroup impacts only for the primary outcome(s) in each domain to minimize concerns about multiple comparisons problem. Consequently, we do not have direct evidence of impacts of the FS initiative on household income at follow-up by baseline-income quartile.

that income impacts might also be larger for households closer to the poverty cut-point than for other households, which help explain the observed reduction in poverty.

One might also question whether or not the impacts of FS on poverty are policy-relevant. This is possible because some households would have connected even in the absence of the low-cost-connection offers under FS and, for those households, the FS is essentially a cash supplement to their income that likely increases consumption of other goods but may not directly impact consumption of electricity. This seems likely for households in the top quartile of household income since the connection rate impact of T&D lines was largest for that group (see Table E.2e). It seems less appropriate for households in other baseline-income quartiles. This suggests that the low-cost-connection offer being considered as a cash supplement by the household may not be the primary explanation for the reduction in poverty.

We found no clear evidence of subgroup differences in the impacts of the FS initiative in our analyses by gender of household head, age of household head, urban location, or baseline income. One difference (impacts on non-electricity consumption by urban/rural location) was statistically significant at the 10 percent level. None of the other differences were statistically significant at the 5 percent level.

C. Impacts of actually connecting to the grid

As noted above, the estimated impacts of T&D lines on connection rates were much lower than expected. This limited the degree to which those components of the energy sector project could directly affect other household outcomes. Indeed, our estimated impacts of actually being connected, summarized in this section, are often substantially larger than the estimate impacts of the T&D lines. These estimates of impacts of being connected to the national grid do not provide direct evidence on the likely future impacts of the T&D lines. However, the estimated impacts of connecting do suggest the potential for increased impacts of the T&D lines if connection rates increase.

Connection to the grid greatly increased households' use of electricity as expected, with connected households using a total of about 82.7 kWh electricity per month from any source. The level of consumption was nearly six times higher than that in the nonconnected households in the study sample. Also as expected, households connected to the grid demonstrated greater use of light bulbs and, in turn, consumption of more light—about five times more in lumen-hours—than did nonconnected households. Connection to the grid also reduced the use of generators, flashlights, car batteries, and kerosene lamps. Interestingly, connected households retained the same number of kerosene lamps, on average, as nonconnected household, thus suggesting that, even after connection to the grid, households may keep kerosene lamps as backup. The reduction in hours of use of kerosene lamps among connected households underpins a 60 percent reduction in the amount of kerosene used per month, but it had no clear impact on the amount of total liquid fuel (kerosene, diesel/gasoline, LPG) used per month or on the use of kerosene stoves for cooking.[86]

[86] We found no statistically significant impacts of the line extensions on use of kerosene. However, the point estimate was negative and suggested a 19 percent reduction relative to the comparison group.

Connection to the grid also tripled the number of electric appliances used by households, with 78 percent of connected households owning a television versus 22 percent of nonconnected households. Connection to the grid also increased the share of households owning a mobile phone by 4 percentage points to 97 percent but, at the same time, allowed households to save about 3,150 TZS per month—the money they would have spent for recharging their phone.

With increased light available at night, connection to the grid increased the time that children spent on studying at night by about 12 minutes per day, but it also increased the time that children watched television by about 73 minutes per day. Connection to the grid also had a small positive impact on children's enrollment in school and increased the likelihood that households had a child attending a school powered by electricity.

Similar to the impacts of the T&D lines, connection to the grid had no clear impact on health outcomes among children and youth or on safety outcomes. It did, however, increase the fractions of households that obtained information on family planning and HIV by around 10 percentage points each.

Connection to the grid had only modest impacts on patterns of time use among women and men (reducing time spent on collecting water and fuel but increasing time spent on socializing and resting, including watching television), but it increased the share of households operating an electrified IGA by 26 percentage points. It also led to a large increase in households' revenue from IGAs—60 to 84 percent higher revenue than among nonconnected households (depending on measures of monthly or annual revenue).

We found large and consistent positive impacts of connection to the grid on various measures of household economic well-being. Connection to the grid increased annual household nonelectric consumption by 27 percent, annual household income by 49 percent, per capita daily consumption by 23 percent, and per capita daily income by 27 percent. The positive impact on resources available to the household was evident in a large reduction in the per capita $1-a-day poverty measure by 16 percentage points (or 24 percent relative to the poverty rate among nonconnected households) and in the per capita $2-a-day poverty measure by 5 percentage points. It appears that at least part of the reason for increased economic well-being was attributable to increased IGA income, which, in turn, may be related to decreased time spent by men and women on collecting fuel and water and decreased time spent by men on cooking, processing, and preparing food.

Despite some evidence of positive impacts on land prices based on the community survey, our analyses of the impacts of the T&D lines, of the FS initiative, and of connection to the grid on household assets neither confirm nor reject the findings from the community survey. As with the results of the T&D lines and FS initiative, the estimated impacts of connection to the grid on total assets are not statistically significant, although the impacts from the community survey showed positive impacts of the T&D lines on residential land prices. However, the point estimate of the impact of connection on total assets is positive and large—indeed, even larger than the estimated 34 percent impact from the community survey. Moreover, even though we found no clear impact of connections on total household assets, we have suggestive evidence that connection to the grid could contribute to household asset development through improved dwelling conditions, use of flush toilets, and piped water in the house.

One partial explanation for the differential findings is that community survey respondents reported on behalf of a much larger number of households than did household survey respondents—by about a 10-to-1 ratio.[87] For this reason alone, we would expect the standard error of the estimated impacts on asset-related measures based on the community survey to be about a third of the size of those from the household survey. Thus, the larger variability in the household asset data do not allow us to conclude with confidence whether the increased residential land price observed at the community level in response to the installation of new electric lines translated to increased asset value for households that connected to the line.

Our subgroup analysis revealed some variation in impacts on a few outcomes, but not a distinctive pattern of impacts for any particular subgroup. We did not find any differences by gender.[88] We found, not surprisingly, that connection to the grid had greater impacts on the monthly amount of electricity consumed from any source among urban versus rural households. We also found that connection to the grid had a larger impact on the likelihood of operating an IGA in households with a head younger than age 25 and in households in the lowest income quartile at baseline. The impacts offer encouraging evidence of the potential for connection to the grid to improve the economic well-being of Tanzania's younger and lower-income population.

The methods used to estimate the impacts of connection to the grid were far less rigorous than the RCT approach used to estimate the impacts of the FS initiative, and perhaps somewhat less rigorous than the methods used to estimate the impacts of the T&D lines which benefited from multiple steps of community-level matching. To address this concern we tested for bias in the estimated impacts of connection to the grid by using two types of IVs—one instrument was based on the RCT for the FS initiative, and the other was based on an institutional rule imposed by TANESCO that makes it far more expensive for households to connect to the grid if they live more than 30 meters away from an electric pole. We found no clear evidence of bias in the impact estimates in the analysis that compared connected households with matched nonconnected households. The result does not rule out the possibility of bias but does provide some assurance that the bias may not be large. Of particular interest, the estimated impacts of connecting on reducing the fraction of households below \$1 and \$2 per day become even larger and remain statistically significant when estimated using the IV approach.

[87] The number of households covered by the community survey was greater than that covered by the household survey for many reasons. First, the household survey only covered households that were not connected or within 30 meters of a new line at baseline. Second, we estimated that about 72 percent of the eligible households in the villages covered by the community survey were located in the subvillages covered by the household survey. Third, we sampled only about 16 percent of the eligible households in the subvillages covered by the household survey. Finally, we achieved about an 80 percent response rate. Multiplication of these fractions yields about 0.09 (= 0.72*0.16*0.80).

[88] Dinkelman (2011) did find larger impacts on employment of being in an electrified community for females than males though the differences were not statistically significant. In Appendix J we discuss our attempt to replicate Dinkelman's analysis.

D. Differences between findings from more and less rigorous evaluation designs

To address our research question about the value of using rigorous research methods, we conducted a within-study-comparison analysis. The goal was to estimate the benefits of all combinations of (1) focusing the comparison group on geographically local areas, (2) controlling for the baseline value of the outcome (a "pretest"), and (3) matching on a rich set of additional covariates in the context of this evaluation. These are all factors that were used in our line extensions and exploratory analyses to varying degrees, and they are also factors that are generally considered essential for reducing bias but whose influence has not yet been tested jointly (Heckman, Ichimura and Todd 1997, 1998; Heckman et al. 1998; Heckman and Hotz 1989). This evaluation provided an opportunity to test the joint importance of all of these factors.

The results of the WSC suggest that all three factors help to reduce bias (as expected) but that, when used in combination, local comparisons and rich covariates were most effective (as they reduced the average bias by 80 percent). Future work could investigate these topics further by (1) selecting samples of comparison households and/or communities that had greater bias in the absence of any adjustments, (2) exploring the pre-tests more completely, (3) testing alternative definitions of what local comparisons mean, and (4) testing alternative definitions of "rich" covariates. Analyzing such variations was not possible, given the time frame of this analysis.

E. Conclusions

We found encouraging evidence suggesting that a general increase in the electrification rates in the parts of Tanzania covered by our study resulted in both economic and noneconomic benefits. At the same time, we found evidence of important cost challenges associated with building the T&D lines, expanding the capacity of the grid to accommodate the new lines, and connecting individual households to the new lines. We also found evidence of challenges associated with trying to realize fully the potential benefits of electrification in two key domains—health and education. The results of our study should be helpful for guiding future initiatives such as those likely to be implemented as part of the Power Africa initiative.

We found no clear evidence of direct impacts of the T&D lines or FS initiative on income. However, we did find that these components of the MCC energy project increased connection rates, and that the FS initiative reduced poverty (measured as per capita consumption of less than $1 per day) within the small set of communities targeted for the low-cost connections offers. Even though the T&D lines and FS initiative did not clearly increase income, our exploratory analysis suggests that actually being connected to the grid increased household income by about 50 percent, and reduced poverty by 16 percentage points suggesting the potential for T&D lines and the FS initiative to have similar impacts if connection rates rise in the future. Previous literature has also been generally encouraging with respect to the economic benefits of electrification, with a few studies finding less promising results (Wamukonya 2001; Bernard and Torero 2009) but many finding positive impacts (Grogan and Sadanand 2013; Khandker et al. 2012; Chakravorty 2014; Khandker et al. 2009; Dinkelman 2011; Van de Walle et al. 2014)—often with magnitudes of impact on income similar to those we found. We suspect that further analyses could be done using our data to explore the role of electricity in the growth and expansion of businesses. Our findings suggest that connection to the electric grid can substantially reduce poverty and play an important role in furthering the UN's Sustainable Development Goal of reducing the poverty rate at least by half by 2030 (UN 2015).

We also found evidence of large positive impacts of the T&D lines and FS initiative on perceived household safety—benefits that may not be reflected in household income because they are effectively externalities. Wamukonya (2001) found similar results. Quantifying these benefits in monetary terms is a nontrivial task, but the value of these benefits needs to be a major consideration in any analysis of electrification's potential benefits (Söderholm and Sundqvist 2003; Metcalf and Stock 2015).

Despite the apparent potential for large economic benefits of electrification, it is important to consider several cost-related challenges that pertain to building new lines, increasing the capacity of the electric grid to handle additional customers, and the connection of individual households to the grid.

The cost of building the T&D lines was large in absolute terms as well as in comparison to economic benefits with respect to estimated impacts on household consumption and income. According to the compact closeout report (MCA-T 2015), the line extensions cost approximately $71.9 million, which is around $6,694 per connected household based on our estimate of about 10,794 connections.[89] In comparison, we estimated the impact of connection to the grid on household consumption of about 1.1 million TZS per household and on income of about 2 million TZS per household. These numbers translate to approximately $500 to $900 at the current exchange rate (2,196 TZS per U.S. dollar).

Even though the costs of the T&D lines are large relative to its annual economic benefits, a number of issues mitigate the cost of building new T&D lines. First, if connection rates rise in the future, they will reduce the cost per connected household. The impacts of the T&D lines on access to the grid and the literature we have reviewed for the evaluation suggests that connection rates could easily double in the coming years (Karhamar et al. 2014; Barron and Torero 2016; Winther 2007). Third, even though our estimates suggest that the T&D lines will probably not pay for itself in the short run, it could pay off over several years if the estimated impacts on household consumption or income remain stable or grow and discount rates are not too high. Fourth, we did not take into account the value to the community of the improved safety associated with night-time light, the increased number of electrified schools and businesses, and/or reduced distances to diagnostic services; these improvements can contribute to the overall economic benefits of the new lines. Fifth, construction of the MCC lines may make it easier for TANESCO to connect additional households by building lines where the MCC lines end. Indeed, we do see that the T&D communities got far more non-MCC lines as well as MCC lines, compared to the comparison communities.

[89] The T&D activity cost a total of around $124 million. Although we do not have the detailed cost break-down from the contract documentation, the compact completion report (MCA-T 2015) suggests that about $71.9 million of this (58 percent) was for the new line extensions. According the report, the rest of the funds were used for rehabilitation of substations that help transmit and distribute electricity.

Another cost challenge faces projects aiming to connect more households to the grid—the introduction of grid electricity to a growing number of households requires additional power, along with the installation of new lines. Without additional power, the new lines may simply shift electricity away from current customers to provide limited amounts to new customers. Our review of the literature pointed to substantial challenges to expanding the capacity of Tanzania's power sector (Ahlborg and Hammar 2014; Miller et al. 2015). Tanzania's Ministry of Energy and Minerals estimated that an overall investment of about $11.4 billion is required over a five-year period (that is, $1.9 billion annually, or about 4 percent of Tanzania's GDP in 2014) to implement the reforms of the energy supply industry envisioned by the government, with three-quarters of the investment allocated for power generation (MEM 2014). It is not clear whether Tanzania's current electricity tariff structure offers a sustainable way to finance these investments while ensuring the appropriate recovery of the costs of capital and operating expenditures.

The high cost of connecting to the grid is also likely to continue to be a major barrier at the household level. The FS initiative was designed to help address these cost issues and appears to have roughly doubled connection rates compared to the impact of the T&D lines. We estimate that MCA-T achieved about 31 percent of its goal of connecting 35,000 households by the time of the follow-up survey, about two to three years after installation of the new lines. If the FS initiative been implemented in all T&D communities, it seems likely that MCA-T would have reached nearly three quarters of its goal. Other research also suggested that reducing connection costs would increase connection rates (Golumbeanu and Barnes 2013; Bernard and Torero 2009; Barron and Torero 2014).

The results from our analysis also suggested two noncost challenges—in the areas of education and health—associated with fully achieving the potential benefits of electrification projects. In the area of education, we found no clear impacts of T&D lines or the FS initiative on hours of studying at night. We did find evidence of beneficial impacts of connection to the grid on children's studying at night, with an increase of about 12 minutes per day. However, connection to the grid also increased children's time spent on watching television by about 73 minutes per day, perhaps constraining the degree to which electricity is able to foster academic outcomes.[90] Similar results have been found on time spent on studying (Khandker et al. 2009a, 2009b, 2012; Bensch 2011). The results of earlier literature for television are somewhat less clear, with two studies finding positive impacts on television ownership (Bernard and Torero 2009; Barkat et al. 2012) and another finding no clear impacts on time spent on watching television (Bernard and Torero 2015).

We found little evidence of beneficial impacts on health-related outcomes. In theory, electrification could improve health outcomes in several ways. In particular, it is plausible that electrification would reduce kerosene and solid fuel use, which, in turn, would improve air quality in the home. However, our evidence suggested that impacts on health are somewhat unclear. We did not find clear impacts of the T&D lines or FS initiative on kerosene use. Connection to the grid did appear to reduce kerosene use, but it did not reduce overall use of liquid or solid fuels. Consequently, it is perhaps not surprising that we saw no clear evidence of

[90] It should be kept in mind that television use may improve academic outcomes (Gentzkow and Shapiro 2008). In addition, it could lead to an increased awareness about one's own country and the rest of the world.

positive impacts on health or pollution outcomes. At least one other study did find evidence that electrification can improve health by reducing kerosene use and thus indoor air pollution (Barron and Torero 2016). However, even that case lacked evidence of a change in the use of solid fuel, which is also a major source of indoor air pollution in many low-income rural communities in developing countries.

Findings from the evaluation suggest that the potential benefits of increasing access and connection to grid electricity in Tanzania are large and spread across a variety of economic and noneconomic domains. However, expanding access to the grid both cost-effectively and sustainably may pose a serious challenge. In particular, it appears that, relative to annual benefits, the effort to bring large numbers of households online involves substantial costs related to building lines, improving capacity, and connecting households. The results of our FS evaluation suggested that a reduction in connection costs would increase connection rates and could thus reduce the cost of building new lines per connected house. Another challenge at the household level relates to education and health. In the area of education, it appears that focused efforts may be needed to ensure that the increased use of television does not offset the potential for improved educational outcomes. In the area of health, it appears that focused 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 underway in other African countries as part of the Power Africa initiative of the U.S. government and related efforts supported by the MCC, USAID, World Bank, and numerous other development partners.

REFERENCES

Ahlborg, Helene, and Linus Hammar. "Drivers and Barriers to Rural Electrification in Tanzania and Mozambique–Grid-Extension, Off-Grid, and Renewable Energy Technologies." *Renewable Energy*, vol. 61, 2014, pp. 117–124.

Angrist, Joshua, and Alan Krueger. "Instrumental Variables and the Search for Identification: From Supply and Demand to Natural Experiments." *Journal of Economic Perspectives*, vol. 15, no. 4, 2001, pp. 69–85.

Angrist, Joshua, and Jörn-Steffen Pischke. *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton, NJ: Princeton University Press, 2009.

Barkat, Abul, S.H. Khan, M. Rahman, S. Zaman, A. Poddar, S. Halim, N.N. Ratna, M. Majid, A.K.M. Maksud, and A. Karim. *Economic and Social Impact Evaluation Study of the Rural Electrification Program in Bangladesh.* Dhaka: Human Development Research Centre and NRECA International Ltd, 2002.

Barnes, Douglas. "Electric Power for Rural Growth: How Electricity Affects Rural Life in Developing Countries (2nd ed.)." Washington, DC: Energy for Development, 2014.

Barron, Manuel, and Maximo Torero. "Short-Term Effects of Household Electrification: Experimental Evidence from Northern El Salvador." Working Paper, March 2014. Available at https://www.ocf.berkeley.edu/~manuelb/research.html. Accessed March 15, 2016.

Barron, Manuel, and Maximo Torero. "Household Electrification and Indoor Air Pollution." Working Paper, January 2016. Available at https://www.ocf.berkeley.edu/~manuelb/research.html. Accessed May 12, 2016.

Bensch, Gunther, Jochen Kluve, and Jörg Peters. "Impacts of Rural Electrification in Rwanda." *Journal of Development Effectiveness*, vol. 3, no. 4, 2011, pp. 567–588.

Bensch, Gunther, Jörg Peters, and Maximiliane Sievert. "The Lighting Transition in Africa – From Kerosene to LED and the Emerging Dry-Cell Battery Problem." Ruhr Economic Papers #579. September 2015.

Bernard, Tanguy. "Impact Analysis of Rural Electrification Projects in Sub-Saharan Africa." *The World Bank Research Observer,* vol. 27, no. 1, February 2012, pp. 33–51.

Bernard, Tanguy, and Maximo Torero. "Welfare Impact of Rural Electrification: 'Short-Term' Evidence from Ethiopia: A Report for the Ethiopian Electric Power Corporation and the World Bank." Washington, DC: International Food Policy Research Institute, December 2009.

Bernard, Tanguy, and Maximo Torero. "Social Interaction Effects and Connection to Electricity: Experimental Evidence from Rural Ethiopia." *Economic Development and Cultural Change*, vol. 63, no. 3, 2015, pp. 459–484.

Bloom, H.S., C. Michalopoulos, and C.J. Hill. "Using Experiments to Assess Nonexperimental Comparison Group Methods for Measuring Program Effects." In *Learning More from Social Experiments*, edited by H.S. Bloom. New York: Russell Sage Foundation, 2005.

Bloom, H., P. Zhu, and F. Unlu. "Finite sample bias from instrumental variables analysis in randomized trials." Working paper. New York: MDRC, 2010.

Burlando, Alfredo. "Transitory Shocks and Birth Weights: Evidence from a Blackout in Zanzibar." September 27, 2013. Available at http://ssrn.com/abstract=2164460. Accessed April 29, 2016.

Central Statistical Agency (Ethiopia) and ICF International. "Ethiopia Demographic and Health Survey 2011." Addis Ababa, Ethiopia, and Calverton, MD: Central Statistical Agency and ICF International, 2012.

Chakravorty, Ujjayant, Martino Pelli, and Beyza Ural Marchand. "Does the Quality of Electricity Matter? Evidence from Rural India." CESifo Working Paper, No. 4457. October 2013. Available at https://ideas.repec.org/p/ces/ceswps/_4457.html. Accessed April 29, 2016.

Chaplin, Duncan, and Arif Mamun. "Quality of Data on Connections to the National Electric Grid for Evaluation of Millennium Challenge Corporation's Energy Project in Mainland Tanzania." Memorandum submitted to Millennium Challenge Corporation. Washington, DC: Mathematica Policy Research, November 23, 2015.

Chaplin, Duncan, Arif Mamun, Thomas Fraker, Kathy Buek, Minki Chatterji, and Denzel Hankinson. "Evaluation of Tanzania Energy Sector Project: Updated Design Report." Washington, DC: Mathematica Policy Research, March 16, 2011.

Chaplin, Duncan, Arif Mamun, Candace Miller, Ali Protik, and John Schurrer. "Evaluation of Tanzania Energy Sector Project: Final Update of Design Report." Washington, DC: Mathematica Policy Research, July 28, 2015.

Chaplin, Duncan, Arif Mamun, and John Schurrer. "Evaluation of the Millennium Challenge Corporation's Electricity-Transmission and Distribution Line-Extension Activity in Tanzania: Baseline Report." Washington, DC: Mathematica Policy Research, November, 2012.

Cook, Nicolas, Richard J. Campbell, Phillip Brown, and Michael Ratner. "Powering Africa: Challenges of and U.S. Aid for Electrification in Africa." Washington DC: Congressional Research Service, September 2015.

Cook, Paul. "Infrastructure, Rural Electrification, and Development." *Energy for Sustainable Development*, vol. 15, 2011, pp. 304–313.

Cook, Thomas D., William R. Shadish, and Vivian C. Wong. "Three Conditions under Which Experiments and Observational Studies Produce Comparable Causal Estimates: New Findings from Within-Study Comparisons." *Journal of Policy Analysis and Management*, vol. 27, no. 4, 2008, pp. 724–750.

Dinkelman, Taryn. "The Effects of Rural Electrification on Employment: New Evidence from South Africa." *American Economic Review*, vol. 101, no. 7, December 2011, pp. 3078–3108.

Energy Sector Management Assistance Program (ESMAP). "Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits." Washington, DC: World Bank Group, May 2002.

Ezzati, Majid, and Daniel M. Kammen. "The Health Impacts of Exposure to Indoor Air Pollution from Solid Fuels in Developing Countries: Knowledge, Gaps, and Data Needs." *Environmental Health Perspectives*, vol. 110, no. 11, November 2002, pp. 1057–1068.

Foster, Vivien, and Cecilia Briceño-Garmendia. "Africa's Infrastructure: A Time for Transformation." Washington, DC: World Bank, 2010.

Foster, Vivien, Jean-Philippe Tre, and Quentin Wodon. "Energy Prices, Energy Efficiency, and Fuel Poverty." Washington, DC: World Bank, September 2000.

Fraker, T. and R. Maynard. "Evaluating Comparison Group Designs with Employment-Related Programs," *Journal of Human Resources*, 22, 1987, pp. 194-227.

Galdo, Jose C., Jeffrey Smith, and Dan Black, "Bandwidth Selection and the Estimation of Treatment Effects with Unbalanced Data," *Annals of Economics and Statistics,* 91/92, 2008, pp. 189-216.

Gentzkow, M. and J.M. Shapiro, "Preschool Television viewing and Adolescent Test scores: Historical evidence from the Coleman study," *The Quarterly Journal of Economics,* vol. 123 no. 1, 2008, pp. 279-323.

Glazerman, S., D.M. Levy, and D. Myers. "Nonexperimental versus Experimental Estimates of Earnings Impacts." *Annals of the American Academy*, vol. 589, no. 1, 2003, pp. 63–93.

Golumbeanu, R., and D. Barnes. "Connection Charges and Electricity Access in Sub-Saharan Africa." Policy Research Working Paper 6511. Washington, DC: World Bank, June 2013.

Grogan, Louise, and Asha Sadanand. "Rural Electrification and Employment in Poor Countries: Evidence from Nicaragua." *World Development*, vol. 43, 2013, pp. 252–265.

Hankinson, Denzel, Lauren Pierce, Duncan Chaplin, Arif Mamun, Minki Chatterji, Shawn Powers, and Elana Safran. "Tanzania Energy Sector Impact Evaluation: Findings from the Zanzibar Baseline Study." Washington, DC: Mathematica Policy Research, March 2011.

Heckman, J.J., and V.J. Hotz. ''Choosing among Alternative Nonexperimental Methods for Estimating the Impact of Social Programs: The Case of Manpower Training.'' *Journal of the American Statistical Association*, vol. 84, Issue 408, 1989, pp. 862–880.

Heckman, James, Hidehiko Ichimura, Jeffrey Smith, and Petra Todd. "Characterizing Selection Bias Using Experimental Data." *Econometrica*, vol. 66, no. 5, 1998, pp. 1017–1098.

Heckman, James, Hidehiko Ichimura, and Petra E. Todd. "Matching as an Econometric Evaluation Estimator: Evidence from Evaluating a Job Training Program." *Review of Economic Studies*, vol. 64, no. 4, 1997, pp. 605–654.

Heckman, James J., Hidehiko Ichimura, and Petra Todd. "Matching as an Econometric Evaluation Estimator." *Review of Economic Studies*, vol. 65, No. 2, April 1998, pp. 261–294.

Heckman, James J. and Jeffrey A. Smith. "The Pre-Program Earnings Dip and the Determinants of Participation in a Social Program: Implications for Simple Program Evaluation Strategies." NBER Working Papers 6983, National Bureau of Economic Research, Inc., 1999.

Heltberg, Rasmus. "Household Fuel and Energy Use in Developing Countries: A Multicountry Study." Washington, DC: Oil and Gas Policy Division, World Bank, 2003.

Hosier, R., and W. Kipondya. "Urban Household Energy Use in Tanzania: Prices, Substitutes, and Poverty." *Energy Policy*, vol. 21, no. 5, 1993, pp. 454–473.

Imai, Kosuke, and David van Dyk. "Causal Inference with General Treatment Regimes: Generalizing the Propensity Score." *Journal of the American Statistical Association*, vol. 99, no. 467, September 2004, pp. 854–866.

Imbens, Guido W., and Donald B. Rubin. *Causal Inference in Statistics, Social, and Biomedical Sciences*. Cambridge, UK: Cambridge University Press, 2015.

Innovation Energie Développement (IED). "United Republic of Tanzania: National Electrification Program Prospectus." Francheville, France: IED, June 2014. Available at http://www.ied-sa.fr/index.php/en/documents-and-links/publications/send/3-reports/33-national-electrification-program-prospectus.html. Accessed April 15, 2016.

International Energy Agency (IEA). "Africa Energy Outlook: A Focus on Energy Prospects in Sub-Saharan Africa." Paris, France: IEA, 2014.

International Energy Agency (IEA). "World Energy Outlook 2015 Electricity Access Database." Paris, France: International Energy Agency, 2015.

International Energy Agency (IEA) and the World Bank. "Sustainable Energy for All 2015—Progress toward Sustainable Energy." Washington, DC: World Bank, June 2015.

Jamasb, Tooraj, Rabindra Nepal, and Govinda R. Timilsina. "A Quarter Century Effort Yet to Come of Age. A Survey of Power Sector Reforms in Developing Countries." World Bank Policy Research Working Paper, no. 7330, July 2015.

Karhammar, Ralph, Ingar Flatlandsmo, Louis Pauchon, and Ryan Anderson. "Impact Assessment of Rural Electrification." Final Report, Norwegian Agency for Development Cooperation (NORAD). Oslo: NORAD Collected Reviews, no. 4, 2014. Available at https://www.norad.no/en/toolspublications/publications/2014/impact-assessment-of-rural-electrification/. Accessed May 12, 2016.

Karhammar, Ralph, Arun Sanghvi, Eric Fernstrom, Moncef Aissa, Jabesh Arthur, John Tulloch, Ian Davies, Sten Bergman, and Subodh Mathur. "Sub-Saharan Africa: Introducing Low-cost Methods in Electricity Distribution Networks." ESMAP Technical Paper 104/06, October 2006.

Ketlogetswe, C., T.H. Mothudi, and J. Mothibi. "Effectiveness of Botswana's Policy on Rural Electrification." *Energy Policy*, vol. 35, no. 2, 2007, pp. 1330–1337.

Khandker, Shahidur R., Douglas F. Barnes, and Hussain A. Samad. "Welfare Impacts of Rural Electrification: A Case Study from Bangladesh." World Bank Policy Research Working Paper, no. 4859, Washington, DC: The World Bank, 2009a.

Khandker, Shahidur R., Douglas F. Barnes, Hussain Samad, and Nguyen Huu Minh. "Welfare Impacts of Rural Electrification: Evidence from Vietnam." World Bank Policy Research Working Paper no. 5057. Washington, DC: The World Bank, September 2009b.

Khandker, Shahidur R., Hussain A. Samad, Rubaba Ali, and Douglas F. Barnes. "Who Benefits Most from Rural Electrification? Evidence in India." World Bank Policy Research Working Paper, no. 6095. Washington, DC: The World Bank, 2012.

Kitonga, John F. "Pre-Assessment Report of the Tanzanian Energy Sector under the Principles of the International Energy Charter and the Energy Charter Treaty." Brussels, Belgium: European Union Energy Charter Secretariat, July 2015.

LaLonde, R. J. (1986). Evaluating the econometric evaluations of training programs with experimental data. *American Economic Review, 76*(4), 604–620.

Lee, Kenneth, Eric Brewer, Carson Christiano, Francis Meyo, Edward Miguel, Matthew Podolsky, Javier Rosa, and Catherine Wolfram. "Barriers to Electrification for 'Under Grid' Households in Rural Kenya." *Development Engineering,* vol. 1, 2016a, pp. 26–35.

Lee, Kenneth, Edward Miguel, and Catherine Wolfram. "Experimental Evidence on the Demand for and Costs of Rural Electrification." Unpublished working paper, 2016b. Available at http://emiguel.econ.berkeley.edu/research. Accessed June 17, 2016.

Lipscomb, Molly, A. Mushfiq Mobarak, and Tania Barham. "Development Effects of Electrification: Evidence from the Topographic Placement of Hydropower Plants in Brazil." *American Economic Journal: Applied Economics,* vol. 5, no. 2, 2013, pp. 200–231.

Lohr, Sharon L. *Sampling: Design and Analysis*. Pacific Grove, CA: Duxbury Press, 1999.

Louw, Kate, Beatrice Conradie, Mark Howells, and Marcus Dekenah. "Determinants of Electricity Demand for Newly Electrified Low-Income African Households." *Energy Policy*, vol. 36, no. 8, 2008, pp. 2812–2818.

Makoye, Kizito. "Tanzania Turns to More Gas and Coal to Meet its Energy Needs." July 23, 2014. Available at http://news.trust.org//item/20140723140401-5rq3c. Accessed April 4, 2016.

Markandya, Anil. "Externalities from Electricity Generation and Renewable Energy. Methodology and Application in Europe and Spain." Cuadernos Economicos de ICE, no. 83, 2010, pp. 85–99.

McCrary, Justin. "Manipulation of the Running Variable in the Regression Discontinuity Design: A Density Test." Journal of Econometrics, vol. 142, no. 2, 2008, pp. 698–714.

Metcalf, Gilbert, and James Stock. "The Role of Integrated Assessment Models in Climate Policy: A User's Guide and Assessment." Discussion Paper 2015-68. Cambridge, MA: Harvard Project on Climate Agreements, March 2015.

Millennium Challenge Account–Tanzania (MCA-T). "Tanzania Energy Sector Project Logic." Internal monitoring and evaluation documentation. Dar es Salaam, Tanzania: MCA-T, January 19, 2012.

Millennium Challenge Account–Tanzania (MCA-T). "Tanzania Compact/Government Completion Report 2008–2015." Dar es Salaam, Tanzania: MCA-T, August 31, 2015.

Millennium Challenge Corporation (MCC). "Millennium Challenge Compact between the United States of America, acting through the Millennium Challenge Corporation, and the Government of the United Republic of Tanzania, acting through the Ministry of Finance." Washington, DC: MCC, February 2008. Available at http://www.mcc.gov/documents/agreements/compact-tanzania.pdf.

Miller, Candace, John Schurrer, Nicholas Redel, Arif Mamun, and Duncan Chaplin. "Millennium Challenge Corporation's Electricity Transmission and Distribution Line-Extension Activity in Tanzania: Qualitative Evaluation." Washington, DC: Mathematica Policy Research, July 22, 2015.

Ministry of Energy and Minerals (MEM), United Republic of Tanzania. "Electricity Supply Industry Reform Strategy and Roadmap 2014–2025." Dar es Salaam, Tanzania: MEM, June 30, 2014.

Ministry of Finance and Economic Affairs, Government of Tanzania (MoF). "United Republic of Tanzania: Poverty and Human Development Report 2009." Dar es Salaam, Tanzania: MoF, 2009.

Ministry of Finance and Economic Affairs, Revolutionary Government of Zanzibar (Zanzibar MoF). "Zanzibar Poverty and Human Development Report 2009." Zanzibar, Tanzania: Zanzibar MoF, 2009.

Nakamura, Alice and Masao Nakamura. "On the Relationships Among Several Specification Error Tests Presented by Durbin, Wu, and Hausman." *Econometrica* vol. 49, no. 6, 1981, pp. 1583–1588.

National Bureau of Statistics (NBS) and ICF Macro. "2010 Tanzania Demographic and Health Survey." Calverton, MD: Tanzania NBS and ICF Macro, 2011.

National Bureau of Statistics (NBS), Tanzania. "Household Budget Survey: Main Report, 2011/12." Dar es Salam, Tanzania: NBS, July 2014.

National Research Council. "Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use." Washington, DC: The National Academies Press, 2010.

Ondraczek, Janosch. "The Sun Rises in the East (of Africa): A Comparison of the Development and Status of the Solar Energy Markets in Kenya and Tanzania." *Energy Policy*, vol. 56, May 2013, pp. 407–417.

Peters, Jörg, Marek Harsdorff, and Florian Ziegler. "Rural Electrification: Accelerating Impacts with Complementary Services." *Energy for Sustainable Development*, vol. 13, no. 1, 2009, pp. 38–42.

Peters, Jörg and Maximiliane Sievert. "Impacts of Rural Electrification Revisited – the African Context." *Journal of Development Effectiveness,* vol. 8, no. 3, 2016, pp. 327-345.

Pfefferman, D. "The Role of Sampling Weights When Modeling Survey Data." *International Statistical Review*, vol. 61, no. 2, 1993, pp. 317–337.

Picard, Robert. "Re: St: Calculating Latitude and Longitude of Nearby Point." *Statalist*, June 9, 2011. Available at http://www.stata.com/statalist/archive/2011-06/msg00479.html. Accessed March 7, 2016.

Ranganathan, V. "Rural Electrification Revisited." *Energy Policy*, vol. 21, no. 2, February 1993, pp. 142–151.

Robins, J., and A. Rotnitzky. "Comments." [Comments on 'Inference for Semiparametric Models: Some Questions and an Answer,'] by J.P. Bickel and J. Kwon. *Statistica Sinica*, vol. 11, 2001, pp. 920–936.] Available at http://www.jstor.org/stable/24306889?seq=1#page_scan_tab_contents. Accessed May 12, 2016.

Rosenbaum, Paul R., and Donald B. Rubin. "The Central Role of the Propensity Score in Observational Studies for Causal Effects." *Biometrika*, vol. 70, no. 1, 1983, pp. 41–55.

Rosenbaum, Paul R., and Donald B. Rubin. "Constructing a Control Group Using Multivariate Matched Sample Methods that Incorporate the Propensity Score." *The American Statistician*, vol. 39, no. 1, 1985, pp. 33–38.

Rubin, Donald. "The Use of Matched Sampling and Regression Adjustment to Remove Bias in Observational Studies." *Biometrics*, vol. 29, no. 1, March 1973, pp. 185–203.

Rubin, Donald B. “Using Propensity Scores to Help Design Observational Studies: Application to the Tobacco Litigation.” *Health Services & Outcomes Research Methodology*, vol. 2, 2001, pp. 169–188.

Rubin, Donald. “The Design versus the Analysis of Observational Studies for Causal Effects: Parallels with the Design of Randomized Trials.” *Statistics in Medicine*, vol. 26, no. 1, 2007, pp. 20–36.

Rural Energy Agency (REA), United Republic of Tanzania. “Annual Report—2012/13.” Dar es Salaam, Tanzania: REA, 2013.

Rural Energy Agency (REA), United Republic of Tanzania. “Annual Report for the Financial Year Ended June 30th, 2014.” Dar es Salaam, Tanzania: REA, 2014.

Schochet, Peter Z. “An Approach for Addressing the Multiple Testing Problems in Social Policy Impact Evaluations.” *Education Review*, vol. 33, no. 6, December 2009, pp. 539–567.

Schurrer, John, Nicholas Redel, Duncan Chaplin, and Arif Mamun. “Evaluation of the Zanzibar Interconnector Activity: Findings from the Hotel Study.” Washington, DC: Mathematica Policy Research, July, 2015.

Silverman, B.W. *Density Estimation for Statistics and Data Analysis*. London, UK: Chapman and Hall, 1986.

Söderholm, Patrik and Thomas Sundqvist. “Pricing Environmental Externalities in the Power Sector: Ethnical Limits and Implications for Social Choice.” *Ecological Economics,* vol. 46, 2003, pp. 333–350.

Spalding-Fecher, Randall. “Health Benefits of Electrification in Developing Countries: A Quantitative Assessment in South Africa.” *Energy for Sustainable Development*, vol. 9, no. 1, March 2005, pp 53–62.

St. Clair, T., T.D. Cook, and K. Hallberg. “Examining the Internal Validity and Statistical Precision of the Comparative Interrupted Time-Series Design by Comparison with a Randomized Experiment.” *American Journal of Evaluation*, vol. 35, no. 3, 2014, pp. 311–327.

Staiger, D., and J.H. Stock. “Instrumental Variables Regression with Weak Instruments.” *Econometrica*, vol. 65, no. 3, 1997, pp. 557–586.

Stock, J., and Yogo, M. “Testing for weak instruments in linear IV regression.” In *Identification and inference for econometric models: Essays in honor of Thomas J. Rothenberg* (pp. 80–108), edited by J. Stock and D. W. K. Andrews. Cambridge: Cambridge University Press, 2005.

Stuart, E. A. “Matching methods for causal inference: A review and a look forward.” *Statistical Science : A Review Journal of the Institute of Mathematical Statistics,* vol. 25, no. 1, 2010, pp. 1–21. http://doi.org/10.1214/09-STS313

Tanzania Electric Supply Company (TANESCO). "History." Dar es Salaam, Tanzania: TANESCO. Available at http://www.tanesco.co.tz/index.php/about-us/historical-background. Accessed February 24, 2017.

The Economist. "Not Such a Bright Idea: Making Lighting More Efficient Could Increase Energy Use, Not Decrease It." August 26, 2010. Available at http://www.economist.com/node/16886228. Accessed September 27, 2012.

Trochim, W. Research Design for Program Evaluation: The Regression-discontinuity Design. Beverly Hills, CA: Sage Publications, 1984.

Uganda Bureau of Statistics (UBOS) and ICF International, Inc. "Uganda Demographic and Health Survey 2011." Kampala, Uganda: UBOS; and Calverton, MD: ICF International, Inc., 2012.

United Nations. "Explanatory Note on the 2014 Human Development Report Composite Indices: Tanzania (United Republic of)," United Nations Development Programme, 2014. Available at http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/TZA.pdf. Accessed June 25, 2015.

United Nations. "Transforming Our World: The 2030 Agenda for Sustainable Development." New York, NY: United Nations, September 2015. Available at https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf. Accessed April 27, 2016.

United Nations. "Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all." Available at http://www.un.org/sustainabledevelopment/energy/. Accessed April 4, 2016.

United States Agency for International Development (USAID). "Power Africa: Investment Brief for the Electricity Sector in Tanzania." Washington, DC: USAID, May 15, 2015a. Available at https://www.usaid.gov/documents/1860/power-africa-investment-guide-tanzania. Accessed April 29, 2016.

United States Agency for International Development (USAID). "Power Africa: What Power Africa Means for Tanzania." Washington, DC: USAID, May 15, 2015b. Available at https://www.usaid.gov/powerafrica/tanzania. Accessed April 29, 2016.

Upadhyay, Ashkay. "Formula to Find Bearing or Heading Angle between Two Points: Latitude Longitude." GIS MAP INFO. Available at http://www.igismap.com/formula-to-find-bearing-or-heading-angle-between-two-points-latitude-longitude/. Accessed March 7, 2016.

Van de Walle, Dominique, Martin Ravallion, Vibhuti Mendiratta, and Gayatri Koolwal. "Long-Term Impacts of Household Electrification in Rural India." World Bank Economic Review. Advance online publication. doi:10.1093/wber/lhv057. Washington, DC: The World Bank, 2015.

Vohra, Divya, Edith Felix, Duncan Chaplin, and Arif Mamun. "Evaluation of the Kigoma Solar Activity in Tanzania: Final report." Washington, DC: Mathematica Policy Research, February 2017.

Wamukonya, Njeri, and Mark Davis. "Socio-economic Impacts of Rural Electrification in Namibia: Comparisons between Grid, Solar, and Unelectrified Households." *Energy for Sustainable Development*, vol. 5, no. 3, September 2001, pp. 5–13.

Williams, J.H., and R. Ghanadan. "Electricity Reform in Developing and Transition Countries: A Reappraisal." *Energy*, vol. 31, no. 6-7, 2006, pp. 815–844.

Winther, Tanja. "Rising Electricity Consumption: Driving Forces and Consequences. The Case of Rural Zanzibar." Oslo: ECEEE Summer Study 2007, pp. 1835–1845.

World Bank. "The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits – an Independent Evaluation Group impact evaluation." Washington, DC: World Bank, 2008a.

World Bank. "Project Performance Assessment Report: Lao People's Democratic Republic Southern Provinces Rural Electrification Project." Report No. 42413. Washington, DC: World Bank, February 4, 2008b.

World Bank. "Addressing the Electricity Access Gap." Washington, DC: World Bank Group, June 2010.

World Bank. "World Development Indicators." Available at data.worldbank.org/products/wdi. Accessed March 30, 2016.

World Health Organization. "Household Air Pollution and Health." Fact sheet No. 292. February 2016. Available at http://www.who.int/mediacentre/factsheets/fs292/en/. Accessed April 29, 2016.

APPENDIX A

DESCRIPTION OF WEIGHTS

This page has been left blank for double-sided copying.

In this appendix, we describe the process used to construct and check the various weights used in our analyses. We constructed four weights as described in Table A.1.

Table A.1. Description of weights

Weight	Description
Financing scheme weight	• Used for main analyses of impacts of financing scheme. • Covers T&D intervention households that responded to the follow-up survey. • Adjusts for sampling (subsidy eligibility) and nonresponse (by region and total migration).
T&D weight	• Used for main analyses of impacts of T&D lines. • Covers all households in the baseline listing that responded to the follow-up survey but does not cover Kigoma or new households. • Same as the financing scheme weight for the intervention group. For the comparison group households, we used kernel matching to assign weights based on the estimated probability of membership in the intervention group.
Exploratory weight	• Used for exploratory analyses of impacts of being connected to the grid. • Covers same households as the T&D weight. • The weight is one for connected households. For not-connected households, we use kernel matching based on the estimated probability of being connected.
Community weight	• Used for analyses of community survey data. • Covers the T&D communities but not Kigoma. • The weight is the size of the community (village or *mtaa)* as reported by the community survey respondent at baseline.

We first describe the construction of the financing scheme weight. Next, we discuss the construction of the T&D lines and exploratory weights and describe the various post-matching diagnostic tests we conducted to assess the quality of our matches.

1. Financing scheme weight

For our intervention group, we created weights to adjust for sampling and survey nonresponse (financing scheme weights). We sampled households in the intervention group based on approximate eligibility for a subsidy pilot intervention that was later replaced by the financing scheme. We based approximate eligibility on whether the household appeared to have two or fewer rooms. The survey team made the determination during the baseline household listing process in the intervention areas. The team then oversampled those households so that 40 percent of the resulting sample qualified versus 25 percent in the sampling frame. We created sampling weights to adjust our sample to be representative of the full population in the intervention group. We calculated the sampling weights (SW_i) as one over the probability of being sampled.

$SW_i = 1/Pr_i$ where Pr_i = probability household i was sampled.

We then adjusted the sampling weights for nonresponse at follow-up by using 18 categories for nonresponse based on region and total migration (in-migration plus out-migration as reported in the community survey). First, we created three categories for total migration. Then we calculated the response rate for each of these categories by region (R_i). Finally we multiplied the sampling weights by the inverse of response rates to create the financing scheme weight (W_i) as

$$W_i = SW_i / R_i$$

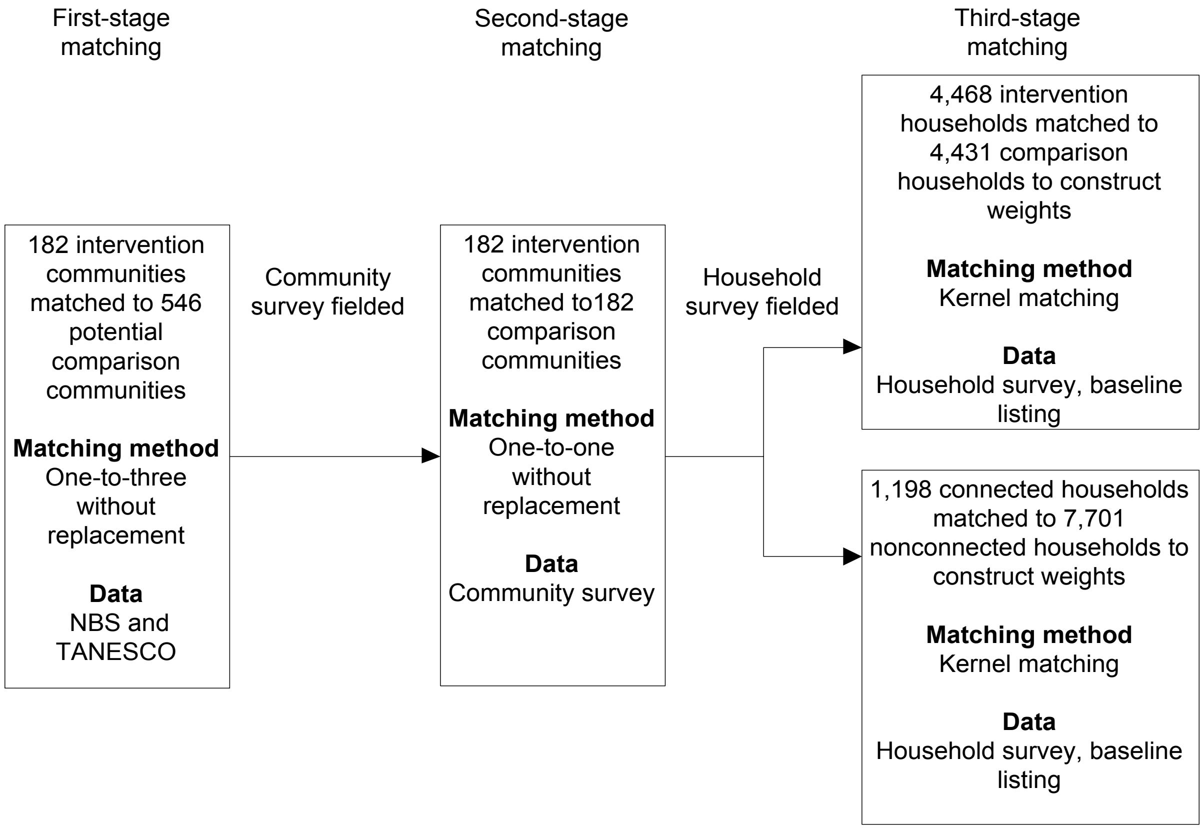
We also created weights for the comparison group to be used for prematch comparisons. The comparison group weights adjust for nonresponse at follow-up by community but not for sampling as we sampled all households with equal probability within a community.

2. T&D lines weight and exploratory weight

We conducted three stages of matching for the T&D lines analyses. Details on the first two stages are covered in Chaplin et al. (2015). In this section, we briefly summarize the first two stages and then go into detail on the third stage used to create the T&D lines weights as well as the matching used to create the exploratory weights. The first two stages of matching at the community level were not expressly designed to help us obtain a matched sample of connected and not connected households for use in the exploratory work, although the process helped ensure that we had variation in connection rates in our sample, that at least some of that variation was at the community level, and that the involved communities were well matched. Thus, we also view the creation of the exploratory weights as a three-stage process.

For the T&D lines analyses, we constructed the weights for the comparison group so that the weighted average of the comparison group outcomes could serve as a defensible counterfactual for those of the intervention group. In the same spirit, for the exploratory analysis, we constructed weights for the nonconnected intervention households to match the connected households based on baseline characteristics. In Figure A.1, we present the three stages of matching. In the remainder of this section, we describe the propensity score matching and weight construction process for both sets of weights.

Figure A.1. Stages of matching used to identify comparison communities and households



a. Estimation of the propensity score

The first step in the construction of the matched sample weights for the T&D lines analysis was to estimate a logistic regression model, where the dependent variable Y_i, indicates whether household *i* was a member of the intervention sample for the T&D lines weight construction or connected to the grid for the exploratory analysis. Then, we regressed Y_i on a *1xk* vector of baseline characteristics X_i:

$$\text{(A-1)} \qquad \Pr(Y_i = 1) = \Lambda(X_i\gamma) = \frac{\exp(X_i\gamma)}{1+\exp(X_i\gamma)}$$

where γ is a *kx1* parameter vector.[91]

[91] Results of this regression are available upon request.

To estimate equation (A-1) for creating the T&D lines weights, we weighted each intervention household by using the financing scheme weight, W_i, and set the weights for the comparison group to one. From the estimation results, we obtained each comparison and intervention household's estimated propensity score as the predicted probability $\hat{q} = \Lambda(X_i\hat{\gamma})$ of belonging to the intervention sample. When estimating equation (A-1) for the exploratory analysis, we set the weights to one for all households.

A critical methodological challenge for propensity score analysis is the specification of a model that satisfies two important assumptions needed for identification of the impacts. First, one needs common support—in other words for each value of a variable included in the model there is a positive probability of being both an intervention and comparison member. Second, the model needs to ensure that conditional on the control variables used, any remaining variation in the treatment variable is correlated with the outcome only because of the causal impact of the treatment. The second assumption implies that the model should satisfy something known as the balance condition (Rosenbaum and Rubin 1983). In theory, this means that for every value of the propensity score, there is no difference in expectation between the intervention and comparison groups for the matching variables used to estimate the propensity score. In practice, we performed a variety of post-matching diagnostics to assess balance, including:

- Checking for common support and dropping observations that were off-support
- Examining the distribution of the propensity scores by intervention (or connection) status pre- and post-matching
- Testing the variables used in the model for statistically significant differences between the comparison and intervention (or connected and nonconnected) households after matching
- Determining whether the variables in the models are jointly significant after matching
- Testing a larger set of baseline variables not included in the model for statistically significant differences between the comparison and intervention (or connected and nonconnected) households after matching

We included the variables in Table A.2 in our T&D lines and exploratory models that are (1) thought to be correlated with characteristics that predict access to electricity (or connection to the grid) and (2) with significant differences between intervention and comparison households.[92] The variables covered many of our key outcomes related to income and energy. We also included gender of the household head, given the interest in gender differences. All variables included in the models were specified as main effects. That is, we did not include interactions or higher order terms in the propensity score specification. In addition to including variables that had a theoretical relevance to access to grid electricity, we iterated through model specifications to achieve balance on the variables included in the model as well as reasonable balance on a larger set of baseline characteristics.

[92] We did not include the T&D and FS status variables in the propensity score matching model for the exploratory analysis of impacts of being connected. Doing so would have enabled us to match on unobserved characteristics associated with those variables but might have reduced the quality of the matches on the variables we did use.

Table A.2. Variables included in the propensity score models

Variable description			
Number of household members	Hours a day key female spent on nonagricultural wage labor	Total annual income (TZS)	Number of television hours per month
Size of community (from baseline listing data)	Hours a day key female spent collecting fuel	Value of home (TZS)	House has an electrifiable roof
Household moved within the last 7.5 months	Hours a day key female spent on farming, gardening, raising animals, and so forth	Amount of light consumed by household (lumen hours)	Presence of flush toilet
Gender of household head	Fraction of students age 5-24 who attend an electrified school	Amount of nonelectric energy produced per month	Presence of a pit toilet
Key female completed primary education	Amount spent on school fees and supplies per year (TZS)	Amount of electricity household produces from grid electricity per month	Total amount spent on energy per year (TZS)[a]
Highest grade key female completed	Presence of an IGA	Electricity expenditures per year (TZS)	Number of rooms in house[b]
Key male completed primary education	Presence of an electrified IGA	Amount spent on dry cell batteries per month (TZS)	
Key male completed secondary education	Number of electrified IGAs	Number of appliances	
Hours per day key female spends reading or studying	Annual consumption (TZS)	Presence of any telephone	
Hours per day females spend being studious	Total household assets (TZS)	Mobile phone charged away from home	

[a] We constructed four binary variables based on the distribution of the amount spent on energy: 0 to 96,000 TZS (minimum to 50th percentile), 90,001 to 216,000 TZS (50th to 75th percentile), 216,001 to 840,000 TZS (75th to 99th percentile), and 840,000 to 9,622,860 TZS (99th percentile to maximum).

[b] We constructed three binary variables: zero or one room, two rooms, and more than two rooms.

b. Matching and weight construction

We describe the propensity score matching method for the T&D lines weights. The method for the exploratory weights is the same as for the T&D lines weights, with the intervention group replaced by connected households and the comparison group replaced by nonconnected households.

We used the propensity score, $\hat{q}_i$, to perform the kernel matching and to construct the matched sample weights for the T&D lines analysis. To make use all of the data collected from our surveys, we chose kernel matching instead of an approach such as nearest neighbor matching that uses only a subset of the potential comparison observations. Kernel matching is a nonparametric technique that uses the weighted averages of all observations in the comparison group to construct a matched comparison group. While other methods may help reduce bias kernel methods can help to reduce variance (Stuart 2010). Larger weights are assigned to comparison households when the ratio of intervention households to comparison households with similar propensity scores is larger. Thus, for example, the comparison households with propensity scores in the right tail of the distribution, as shown in Figure A.2 below, received larger weights relative to those near the modes. To describe this process, we define T to be the set of intervention households and C to be the set of comparison households. Similar to Heckman et al. (1998), each comparison group member for the T&D lines analysis i was assigned a matched sample weight by using the following formula:

$$\text{(A-2)} \qquad W_i^M = \sum_{j \in T} W_i^{KM}\left(j\right)$$

where j is the index for intervention households and $W_i^{KM}\left(j\right)$ is a weight based on the kernel matching given by

$$\text{(A-3)} \qquad W_i^{KM}\left(j\right) = \frac{W_j W_i K\left(\hat{q}_j - \hat{q}_i\right)}{\sum_{k \in C} W_k K\left(\hat{q}_j - \hat{q}_k\right)}$$

and K(.) is a symmetric Gaussian kernel function

$$\text{(A-4)} \qquad K(u) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{u}{h}\right)^2}$$

where h, the bandwidth, is positive. The weights for the comparison households are set to one in equation (A-3). Following Silverman (1986), we selected the optimal bandwidth that minimizes the mean integrated squared error of the estimated non-parametric regression of the untreated outcome on the estimated propensity score (Galdo, Black and Smith, 2008). This is given by

$$\text{(A-5)} \qquad h = 0.9 * A * N^{-\frac{1}{5}}$$

where $A = \min(IQR / 1.34, \hat{\sigma})$ of the distribution of the propensity scores $\hat{q}$, IQR is the interquartile range of the sample, and N is the number of households.

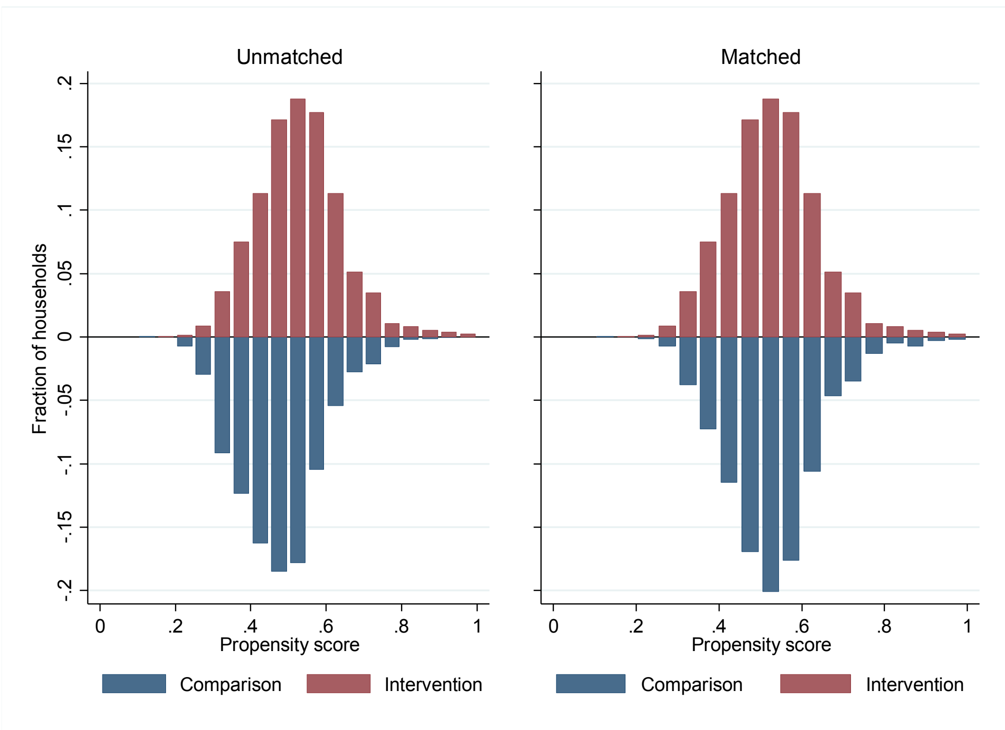
Intuitively, when matching to intervention household j, equation (A-3) assigns a weight $W_i^{KM}(j)$ to each comparison household i that measures how well comparison household i is matched to intervention household j relative to how well all other comparison households are matched to household j. This intermediate weight is based on a kernel function that decreases in the absolute value of the difference in propensity scores $\left(\hat{q}_j - \hat{q}_i\right)$ between households i and j. The denominator is a weighted average of the kernel across all comparison households, when compared to household j. Using equation (A-2), we summed these intermediate weights across all intervention households and used the resulting W_i^M matched sample weights to estimate differences in outcomes at follow-up. Because the kernel matching process did not change the intervention household weights, we defined $W_j^M = W_j$ for each intervention household. In the exploratory analysis, we set the weight for connected households to one.

c. Assessing match quality: T&D lines

After estimating the propensity score for the T&D lines analysis, we conducted a variety of post-matching diagnostics to determine the quality of our matches. We generally found good balance in our matches across many observed characteristics. First, we ensured that all of the observations included in our analysis were on-support. Comparisons were off-support if their propensity score was higher than the maximum or less than the minimum of the estimated score for intervention households. Similarly, intervention households were off-support if their propensity score was higher than the maximum or less than the minimum of the estimated score for comparison households. We found that two households were off-support for the T&D lines analysis, reducing the analytic sample for the T&D lines analysis to 8,897 households.

Next, we checked the distributions of the propensity scores and found improved overlap in the distribution of the propensity scores after applying the weights to the propensity score (Figure A.2). In addition, even the unmatched propensity scores appeared to be fairly well balanced which suggests that selection on observed variables is a reasonable identification strategy in this context.

Figure A.2. Propensity score distribution before and after matching: T&D lines model



Source: Mathematica analysis of Tanzania baseline household survey and listing data.

In Table A.3, we show the diagnostic statistics of the propensity scores by intervention status for the intervention and comparison group households that were on-support. Overall and across the quartiles, the absolute differences in the mean intervention and mean comparison propensity scores were less than 0.01. The difference was statistically significant in the third quartile, but again the difference was small in absolute terms and not jointly significant across quartiles. We also found substantial improvement in the standardized bias after matching. The standardized bias is the difference between the mean propensity scores of the intervention and comparison groups divided by their pooled standard deviation (Rosenbaum and Rubin 1985).[93]

[93] The pooled standard deviation is the square root of the average of the variances of the intervention and comparison groups.

Table A.3. Propensity score diagnostic statistics: T&D lines model

	Mean (intervention)		Mean (comparison)						Standardized bias[a]	
	Unmatched	Matched	Unmatched	Matched	Difference (unmatched)	*p*-value	Difference (matched)	*p*-value	Unmatched	Matched
Whole sample	0.5286	0.5286	0.4753	0.5275	0.053	0.0000	0.0012	0.6225	0.483	0.011
Quartile 1	0.3934	0.3934	0.3417	0.3934	0.052	0.0000	-0.0001	0.9706	1.181	-0.001
Quartile 2	0.4914	0.4914	0.4371	0.4909	0.054	0.0000	0.0005	0.5234	2.644	0.026
Quartile 3	0.5586	0.5586	0.5058	0.5564	0.053	0.0000	0.0023	0.0119	2.731	0.117
Quartile 4	0.6713	0.6713	0.6167	0.6694	0.055	0.0000	0.0019	0.6255	0.741	0.025
Quartiles 1 through 4 (joint F-test)						0.0000		0.6958		

Source: Mathematica analysis of Tanzania baseline household survey and listing data.

[a] The standardized bias is the difference between the mean propensity scores of the intervention and comparison groups divided by their pooled standard deviation, where the pooled standard deviation is the square root of the average of the variances of the intervention and comparison groups.

After examining the characteristics of the propensity score, we looked at diagnostic information on the variables used in the propensity score model and a larger set of baseline variables. Our first set of tests searched for statistically significant differences by intervention status for the baseline variables in the propensity score model. We approached the test in two ways. First, we did not cluster our standard errors at the community level—a more conservative approach. Before matching, 28 variables included in the model were statistically different by intervention status at the 5 percent level using a two tailed test. The Wald χ^2 statistic for the prematch model was 473.17 (df = 38)[94] with $p > \chi^2 = 0.00$, indicating that the variables were jointly significant in predicting intervention status. After matching, two variables remained significant at the 5 percent level (amount of electricity the household produces per month in kWh and whether the house had an electrifiable roof). When we applied our matched sample weights, we failed to reject the hypothesis that the variables do not predict intervention status (Wald χ^2 = 35.80, df = 38, $p > \chi^2 = 0.57$).

We again conducted the same tests, but this time we clustered the standard errors at the community level. One variable remained significant at the 5 percent level (amount of electricity the household produces per month in kWh), and we again failed to reject the hypothesis that the variables are jointly insignificant in predicting intervention status (Wald χ^2 = 22.09, df = 38, $p > \chi^2 = 0.98$).

For our next diagnostic test, we tested for differences in a larger set of 192 variables in order to assess balance further (see Appendix Table B.2). We selected the variables to cut across several domains and to avoid the inclusion of sets of variables that capture almost exactly the same concept (for example, connection rates based on listing and household data). Examples of the variables in the set of 192 are the time spent socializing, time spent on personal hygiene, presence of piped water in the house, time spent cooking, and use of charcoal. We found 14 variables with significant differences at the 5 percent level by intervention status and 22 variables at the 10 percent level. The numbers do not differ statistically from what we would expect by chance.

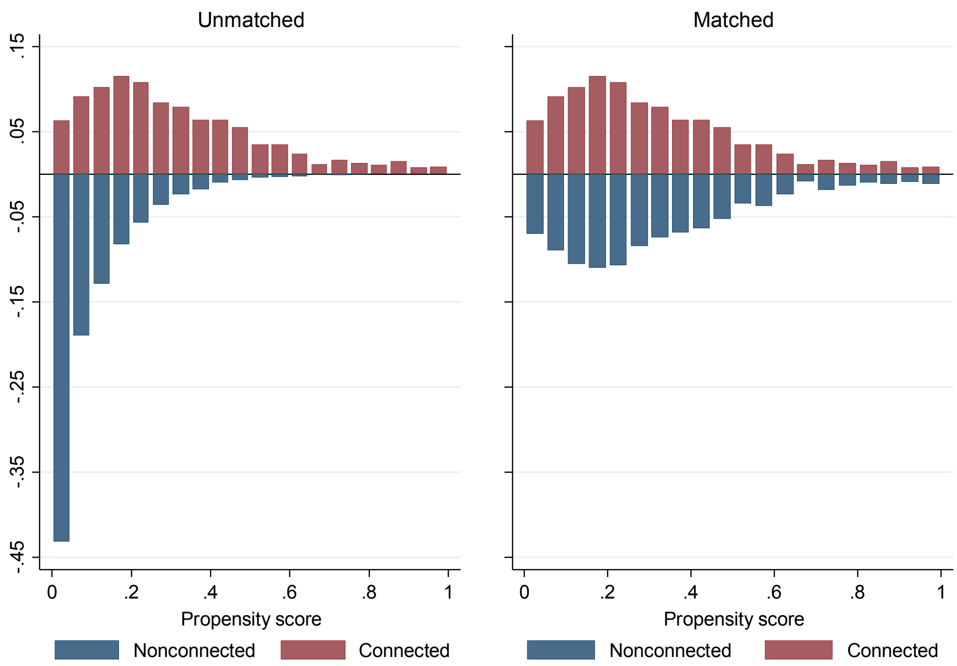
d. Assessing match quality: Exploratory analysis

We conducted the same set of post-matching diagnostics for the exploratory propensity score model and again found good balance after matching along observed characteristics. Again, we first checked for off-support observations and found that 81 households were off-support, thus reducing the analytic sample for the exploratory analysis to 8,818 households.

Our check of the distributions of the propensity scores showed improved overlap in the distribution of the propensity scores after the applying weights to the propensity score (Figure A.3).

[94] We dropped three variables because of collinearity. As a result, there were 38 degrees of freedom for the chi-squared test rather than 41.

Figure A.3. Propensity score distribution before and after matching: Exploratory model



Source: Mathematica analysis of Tanzania baseline household survey and listing data.

In Table A.4, we show the diagnostic statistics of the propensity scores by connection status for the households that were on-support. Overall and across the quartiles, the absolute differences in the mean intervention and mean comparison propensity scores were less than 0.005. The differences were not statistically significant, and we found substantial improvement in the standardized bias.

Table A.4. Propensity score diagnostic statistics: Exploratory model

	Mean (connected)		Mean (nonconnected)						Standardized bias[a]	
	Unmatched	Matched	Unmatched	Matched	Difference (unmatched)	*p*-value	Difference (matched)	*p*-value	Unmatched	Matched
Whole sample	0.3117	0.3117	0.1073	0.3093	0.2045	0.0024	0.0000	0.7184	1.1637	0.0139
Quartile 1	0.0840	0.0840	0.0106	0.0798	0.0734	0.0043	0.0000	0.0059	2.586	0.1502
Quartile 2	0.2027	0.2027	0.0407	0.2003	0.1620	0.0023	0.0000	0.3461	6.4628	0.0936
Quartile 3	0.3420	0.3420	0.1035	0.3397	0.2385	0.0023	0.0000	0.6396	6.0349	0.0589
Quartile 4	0.6190	0.6190	0.2743	0.6179	0.3447	0.0011	0.0000	0.9572	2.4312	0.0077
Quartiles 1 through 4 (joint F-test)						0.0000		0.8995		

Source: Mathematica analysis of Tanzania baseline household survey and listing data.

[a] The standardized bias is the difference between the mean propensity scores of the intervention and comparison groups divided by their pooled standard deviation, where the pooled standard deviation is the square root of the average of the variances of the connected and nonconnected groups.

Again, we looked at diagnostic information on the variables used in the propensity score model and a larger set of baseline variables. For our first set of tests, we examined statistically significant differences by connection status for the baseline variables in the propensity score model without clustering the standard errors at the community level. Before matching, 36 variables included in the model were statistically different by intervention status at the 5 percent level using a two tailed test. The Wald χ^2 statistic for the prematch model was 2,469.38 (df = 38) with $p > \chi^2 = 0.00$, indicating that the variables were jointly significant in predicting intervention status. After matching, one variable remained significant at the 5 percent level (amount of electricity the household produces per month in kWh). When we applied our matched sample weights, we failed to reject the hypothesis that the variables are jointly insignificant in predicting intervention status (Wald $\chi^2 = 35.25$, df = 38, $p > \chi^2 = 0.60$).

We next conducted the same tests, but this time we clustered the standard errors at the community level. No variables remained significant at the 5 percent level, and we again failed to reject the hypothesis that the variables are jointly insignificant in predicting intervention status (Wald $\chi^2 = 25.03$, df = 38, $p > \chi^2 = 0.95$).

Finally, we tested for differences in the larger set of 192 variables in order to assess balance further (see Appendix Table B.4). We found 10 variables with significant differences at the 5 percent level by intervention status and 13 variables at the 10 percent level. In both cases, the numbers do not differ from what we would expect by chance.

3. Community weight

For our estimation of T&D lines impacts at the community level, we constructed a weight that is the size of the community (village or *mtaa)* as reported by the community survey respondent at baseline. The weight allows us to generalize the results of the community survey to the larger set of households in the community.

This page has been left blank for double-sided copying.

APPENDIX B

BASELINE EQUIVALENCE TABLES

This page has been left blank for double-sided copying.

In this appendix, we present the tables showing baseline equivalence for the analytic sample used for the impact analysis of the T&D lines, the FS initiative, and connection to the grid. For the T&D lines impact analysis, we show baseline equivalence estimates for community-level characteristics (Table B.1) as well as household-level characteristics post-matching (Table B2); for the FS and exploratory impact analysis of connections, we show only baseline equivalence of household-level characteristics (Tables B.3 and B.4, respectively).

Table B.1. T&D lines impact analysis: Baseline equivalence of community characteristics

	Intervention		Comparison			
Community characteristics at baseline	**Mean**	**Sample size**	**Mean**	**Sample size**	**Difference**	***p*-value**
Connection rates						
Community connected to grid at baseline	0.11	177	0.07	180	0.04**	0.04
Community has access to grid at baseline	0.42	178	0.37	180	0.05	0.34
Community uses isolated grid at baseline	0.25	178	0.29	180	-0.04	0.37
Community uses generators at baseline	0.84	178	0.83	180	0.01	0.81
Communities uses solar, windmill, or other electric sources at baseline	0.73	178	0.76	180	-0.03	0.50
Composition and mobility						
Number of households in community at baseline reported by the community survey respondent	1,004.22	178	841.89	180	162.33	0.15
Community classified as *mtaa* at baseline	0.28	178	0.22	180	0.06	0.20
Energy use						
Community has access to kerosene at baseline	0.96	178	0.99	180	-0.03**	0.03
Community has access to diesel or petrol at baseline	0.51	178	0.45	180	0.06	0.29
Community has access to firewood, charcoal, or dung at baseline	0.86	178	0.85	180	0.01	0.80
Education and child time use						
Community has electrified school at baseline	0.25	178	0.13	180	0.11	0.01
Distance to nearest preprimary school at baseline (km)	0.91	178	0.71	180	0.20	0.67
Distance to nearest primary school at baseline (km)	0.28	178	0.20	180	0.08	0.40
Distance to nearest secondary school at baseline (km)	2.78	178	3.90	180	-1.12	0.03
Health and safety						
Community has a health facility at baseline	0.44	178	0.36	180	0.08	0.11
Community has electrified health facility at baseline	0.99	178	0.99	180	0.00	0.99
Community has any health facility open at night at baseline	0.12	178	0.10	180	0.02	0.48
Distance to nearest health facility at baseline (km)	1.92	178	3.22	180	-1.30***	0.00
Community has health center at baseline	0.07	178	0.07	180	0.00	0.86
Community has electrified health center at baseline	0.88	178	0.89	180	-0.01	0.71

Table B.1. (*continued*)

Community characteristics at baseline	Intervention Mean	Intervention Sample size	Comparison Mean	Comparison Sample size	Difference	*p*-value
Community has a health center open at night at baseline	0.06	178	0.05	180	0.01	0.79
Distance to nearest health center at baseline (km)	10.94	178	13.13	180	-2.18	0.13
Community has dispensary at baseline	0.37	178	0.31	180	0.06	0.23
Community has electrified dispensary at baseline	0.57	178	0.59	180	-0.02	0.76
Community has a dispensary open at night at baseline	0.04	178	0.03	180	0.01	0.57
Distance to nearest dispensary at baseline (km)	2.73	177	4.09	180	-1.36*	0.07
Community has diagnostic laboratory at baseline	0.12	178	0.16	180	-0.04	0.31
Community has electrified diagnostic laboratory at baseline	0.89	178	0.90	180	-0.01	0.83
Community has a diagnostic laboratory open at night at baseline	0.06	178	0.04	180	0.01	0.61
Distance to nearest diagnostic laboratory at baseline (km)	9.76	178	11.65	180	-1.89	0.21
Community has hospital at baseline	0.03	178	0.03	180	0.00	0.99
Community has electrified hospital at baseline	0.98	178	0.99	180	-0.01	0.66
Community has a hospital open at night at baseline	0.03	178	0.03	180	0.00	0.99
Distance to nearest hospital at baseline (km)	30.56	178	37.58	180	-7.03**	0.03
Distance to obtain vaccine at baseline (km)	0.73	178	0.85	180	-0.12	0.68
Distance to obtain X-ray at baseline (km)	25.19	178	29.22	180	-4.04	0.14
Distance to obtain malaria test at baseline (km)	7.02	178	10.99	180	-3.98***	0.01
Distance to obtain HIV test at baseline (km)	4.44	178	8.68	180	-4.25***	0.00
Distance to nearest health service at baseline	0.61	178	0.78	180	-0.17	0.55
Most people get piped water in community at baseline	0.37	178	0.28	180	0.09*	0.08
Community has a police station at baseline	0.14	178	0.12	180	0.02	0.50
Business and adult time use						
Community has at least one electrified business at baseline	0.79	178	0.77	180	0.02	0.65
Fraction of businesses in community electrified at baseline	0.36	177	0.33	178	0.03	0.28
Community has electrified repair shop at baseline	0.14	178	0.14	180	0.00	0.97
Community has electrified tea, coffee shop, guest house, or hotel at baseline	0.33	178	0.27	180	0.06	0.22
Community has other electrified businesses at baseline	0.76	178	0.77	180	0.00	0.95
Community has weekly market at baseline	0.25	178	0.23	180	0.03	0.58
Community has police station, post office, or bank at baseline	0.15	178	0.14	180	0.01	0.85

Table B.1. (*continued*)

Community characteristics at baseline	Intervention		Comparison		Difference	*p*-value
	Mean	Sample size	Mean	Sample size		
Main source of income in community is farming, fishing, livestock, or hunting at baseline	0.87	178	0.91	180	-0.05	0.17
Economic well-being						
Natural log of the price of land in the community at baseline	13.57	178	13.38	180	0.19	0.33
Most people in community have mobile phones at baseline	0.49	178	0.45	180	0.04	0.46
Other regression controls						
Community connected to national or isolated grid at baseline	0.57	178	0.54	180	0.02	0.66
Community accessible by paved road at baseline	0.62	178	0.58	180	0.03	0.50
Community has electrified post office at baseline	0.03	178	0.06	180	-0.03	0.22
Community has a subvillage at baseline	0.64	178	0.71	180	-0.07	0.19
Distance to nearest regional capital at baseline	30.02	178	34.68	180	-4.66	0.12
Number of households in community surveyed in listing data	298.25	178	176.16	180	122.09***	0.00
Community has a secondary school at baseline	0.42	178	0.34	180	0.08	0.13
Community has a public water supply project in past two years	0.36	178	0.32	180	0.04	0.39

Source: Tanzania energy sector baseline community survey.

TZS = Tanzanian shillings.

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

Table B.2. T&D lines impact analysis: Baseline equivalence of household characteristics

Household characteristics at baseline	Intervention coefficient	*p*-value
Air conditioning/fan hours per month	-0.39	0.49
Any household member has a phone	0.00	0.88
Small batteries used per month	-0.01	0.85
Annual expenditure on light bulbs (TZS)	-578	0.77
Monthly expenditure on candles (TZS)	-844	0.13
Monthly amount of candles used (kg)	-0.03**	0.04
Amount of external pollution from carbon produced per month (kg CO_2)	4.60	0.70
Monthly amount of charcoal used (kg)	0.16	0.98
Spending on cigarettes and alcohol in last 7 days (TZS)	90	0.57
Household moved in last 7.5 months	0.00	0.87
Annual household consumption (TZS)	49,172	0.84
Cooking hours per month	-4.71	0.45
Monthly amount of crop used by household (kg)	-1.06	0.43
Light-hours per month	-5.72	0.65
Current price of dry cell batteries	-14	0.81
Monthly amount of electricity from dry cell batteries (kWh)	0.01	0.25
Monthly expenditure on dry cell batteries (TZS)	74	0.81
Monthly amount of dung used (kg)	-0.07	0.20
Annual expenditure on electric appliances (TZS)	249	0.75
Expenditure on electricity in last 30 days (TZS)	201	0.32
Annual expenditure on electricity (TZS)	5,402	0.48
Monthly amount of electricity from any source consumed by household (kWh)	17.45*	0.07
Energy generation hours per month (kWh)	-0.04	0.99
Annual household expenditure on energy (TZS)	360	0.99
Amount of electricity produced from generators and car batteries (kWh)	0.98	0.71
Amount of nonelectric energy produced from solid fuel, liquid fuel, and dry cell batteries (kWh)	0.49	0.99
Monthly expenditure on nonelectric energy—farmer (TZS)	6,814	0.28
Household has flush toilet	0.00	0.89
Annual household food expenditure (TZS)	-29,357	0.76
Fraction of household members female	-0.01*	0.08
Annual expenditure on solid, liquid, battery, and grid electricity (TZS)	-570	0.86
Monthly amount of diesel used by household (liter)	-0.12	0.81
Spending on grid electricity in last 30 days (TZS)	111***	0.00
Monthly amount of grid electricity used by household (kWh)	0.60***	0.01
Age of household head	-0.89	0.17
Household head married	-0.02	0.32
Whether household head age 18 to 24	0.01	0.10
Heating hours per month	-0.02	0.56
Household had an adult member who suffered health problems	-0.02	0.43
Household head is female	-0.01	0.73
Any household member age 15 or older missed work in last 30 days due to illness	-0.02**	0.04
Number of household members	0.01	0.96
Household received HIV information from television/radio/internet/telephone in last 30 days	-0.02	0.18
Value of home (TZS)	454,077	0.61

Table B.2. (*continued*)

Household characteristics at baseline	Intervention coefficient	*p*-value
Household is electrifiable based on wall and roof material	0.00	0.90
Monthly IGA expenditure on electricity (TZS)	767	0.57
Monthly IGA expenditure on nonelectric fuel (TZS)	3,349	0.67
Annual household income (TZS)	-14,975	0.97
Fuel cost—kerosene (TZS)	-93	0.38
Monthly amount of kerosene used by household (liter)	1.11	0.29
Household has any landline telephone	0.00	0.51
Toilet type—latrine	0.00	0.96
Monthly amount of liquid fuel used by household for appliances (liter)	1.05	0.46
Monthly amount of LPG used by household (liter)	0.14	0.59
Monthly amount of light consumed by household (lumen-hours)	5,544	0.49
Monthly expenditure on nonelectric energy—manufacturing IGA (TZS)	633	0.41
Number of IGAs—manufacturing sector	0.00	0.93
Number of IGAs—medical	0.00	0.88
Annual medical expenses (TZS)	-4,178	0.35
Monthly expenditure on nonelectric energy—medical IGA (TZS)	3	0.58
Household owns at least one mobile phone	0.00	0.89
Number of appliances owned by household	0.04	0.86
Number of children (under age 18) in household	0.01	0.95
Number of IGAs operated by household	-0.07	0.17
Number of complete years lived in household	-0.24	0.70
Water sources—river/lake/spring/pond/rain	-0.04	0.31
Net income after adjusting for homeownership status (TZS)	-15,997	0.97
Household had no expenditure on food	0.01	0.62
Toilet type—no toilet	0.00	0.47
Total household assets minus home value (TZS)	371,271	0.53
Annual nonelectric energy expenditure (TZS)	-5,143	0.75
Nonwage income	-227,271*	0.05
Water sources—other	0.02**	0.04
Other household appliance used hours per month	-0.10	0.96
IGA at other location	-0.04	0.29
Toilet types—other	0.00	0.91
Other work tool, hours per month	-0.26	0.94
Paid employee at IGA in last year	-0.06	0.47
Household has indoor piped water during rainy and dry seasons	-0.01	0.58
Toilet types—pit toilet	0.00	0.77
Monthly liquid fuel expenditure (TZS)	-838	0.59
Monthly solid fuel expenditure (TZS)	-279	0.89
Radio and CD hours per month	7.32	0.47
Refrigerator hours per month	2.71	0.49
Whether household rents home	0.01	0.45
Annual rent (TZS)	1,095	0.45
Number of IGAs—repair shops and other IGAs	-0.03	0.32
Monthly expenditure on nonelectric energy—repair and other IGA (TZS)	-2,720	0.49
Roof of house is electrifiable	-0.02	0.43
Annual expenditure on satellite dish and cable television (TZS)	5,148	0.45
Annual expenditure on school fees and supplies (TZS)	6,715	0.82
Number of rooms household has for sleeping	-0.14**	0.03

Table B.2. (*continued*)

Household characteristics at baseline	Intervention coefficient	*p*-value
Number of IGAs—small vendors	0.02	0.27
Monthly expenditure on nonelectric energy—small vendor	-1,374	0.25
Hours per day spent on socializing—female	-0.09*	0.07
Annual expenditure on solar photovoltaic system (TZS)	3,348	0.31
Monthly amount of solid fuel used (kg)	-1.53	0.55
Monthly amount of internal pollution from soot produced (g black carbon)	0.00	1.00
Monthly amount of straw used (kg)	-0.07	0.20
Annual tax (TZS)	-95	0.90
Total household assets (TZS)	826,898	0.52
Monthly total expenditure on solid and liquid fuel (TZS)	-980	0.72
Monthly total electricity used (kWh)	2.27	0.94
Family has male head, female spouse, no other adults	-0.03	0.10
Transportation hours per month	7.82	0.61
IGA—truck or vendor	0.00	0.78
Hours per day spent on watching television—female	0.02	0.65
Television hours per month	1.03	0.68
IGA unpaid staff in last year	-0.11	0.44
Water sources—water vendor, kiosk, water truck/tanker service	0.01	0.56
Wall of house is electrifiable	0.03	0.14
Fraction who have spoken to a ward development officer	0.05***	0.00
Fuel cost—wood (TZS)	-18	0.24
Monthly amount of wood used by household (kg)	-0.57	0.95
Number of years (including partial years) lived in household	-0.25	0.69
Monthly amount of water from pumps (liter)	36,193.07*	0.06
Water sources—outside dwelling	-0.09	0.13
Water pump hours per month	0.44	0.30
Water sources—well and borehole	0.11**	0.01
Completed any education—key male	0.00	0.96
Household operates any IGA with grid electricity	0.00	0.91
Assets of females if female head or spouse of head in home (TZS)	246,053	0.36
Assets of males if male head or spouse of head in home (TZS)	-168,003	0.66
Average age of IGA owners	-0.72	0.11
Mobile phone monthly bill	417	0.26
Charge mobile phone away from home	0.00	0.92
Charge mobile phone at home or at neighbor's house	0.00	0.92
Hours per day spent on taking care of children—female	0.01	0.85
Highest grade completed—key female	0.05	0.81
Highest grade completed—key male	0.04	0.84
Hours per day spent on cooking and preparing food—female	0.01	0.91
Hours per day spent on resting—female	-0.02	0.73
Average education (grade completed) of IGA owners	0.13	0.44
Number of electric protective devices (surge protectors, voltage stabilizers, regulators, and so forth)	0.00	0.76
Hours per day spent on farming, gardening, poultry and livestock, animal grazing, fishing—female	-0.01	0.96
Number of IGAs—farmers	-0.06*	0.06
Monthly expenditure on nonelectric energy—farm/small vendor IGA (TZS)	5,440	0.40
Hours per day spent on cooking, processing, and preparing food—female	-0.01	0.89

Table B.2. (*continued*)

Household characteristics at baseline	Intervention coefficient	*p*-value
Fraction of students age 5 to 24 who attend school with electricity	0.00	0.78
Fraction of household members age 5 to 24 who attend school	-0.02	0.20
Fraction of IGA—truck or vendor	0.01	0.74
Fraction of IGA—other location	-0.01	0.71
Hours per day spent on collecting fuel—female	0.01	0.90
Household member age 15 or older unable to work due to illness—female	-0.02**	0.05
Household member age 15 or older unable to work due to illness— male	-0.01	0.12
IGA at household	-0.01	0.61
Total IGA energy expenditures (TZS)	4,121	0.62
Number of IGAs owned by females	-0.04**	0.04
Monthly IGA income—top three IGAs only (TZS)	-91,768	0.64
Monthly IGA income (TZS)	44,473	0.87
Number of IGAs owned by males	-0.02	0.53
Total number of IGAs	-0.06**	0.04
Number of IGAs with electricity	0.00	0.89
Number of IGAs using nonelectric energy	0.04*	0.09
Annual income—female (TZS)	-111,795	0.49
Annual income—male (TZS)	357,747	0.24
Total phone monthly bills—use plus charging (TZS)	599	0.19
Cost to recharge mobile phone (TZS)	4	0.49
Multitasking hours—child	-0.10	0.12
Multitasking hours—female	-0.25	0.39
Multitasking hours—male	-0.10	0.52
Hours per day spent on sleeping at night—female	0.04	0.48
Hours per day spent on other household chores—female	-0.02	0.67
Hours per day spent on other IGAs—female	0.00	1.00
Hours per day spent on other leisure activities—female	-0.01	0.78
Hours per day spent on other household activities—female	-0.18**	0.04
Hours per day spent on other household activities—male	-0.06	0.56
Hours per day on other time use—female	0.00	0.96
Hours per day spent on personal hygiene—female	-0.04*	0.08
Completed primary education—key female	0.00	0.90
Completed primary education—key male	0.00	0.86
Hours per day spent on processing food—female	-0.02	0.36
Hours per day spent on listening to radio—female	0.05	0.67
Hours per day spent on reading and studying—female	0.00	0.85
Mobile phone recharge costs per week (TZS)	54	0.17
Hours per day spent on religious practices—female	-0.07	0.15
Hours per day spent on repairing clothes, basket, and so forth— female	-0.02	0.47
Hours per day spent at school—female	0.00	0.88
Completed secondary education—key female	0.00	0.89
Completed secondary education—key male	0.00	0.92
Hours per day spent on shopping—female	-0.08**	0.02
Hours per day spent on visiting neighbors or on other leisure activities—female	-0.10	0.21
Hours per day spent on visiting neighbors or on other leisure activities—male	-0.08	0.57
Hours per day spent on studying—female	0.00	0.83
Hours per day spent on studying—male	-0.07	0.15
Hours per day spent on taking meals—female	-0.03	0.21

Table B.2. (*continued*)

Household characteristics at baseline	Intervention coefficient	*p*-value
Completed tertiary education—key female	0.00	0.83
Completed tertiary education—key male	0.01	0.38
Hours per day spent on collecting water—female	-0.01	0.81
Average year IGA established	1.01**	0.04
Hours per day spent on wage labor in nonagriculture—female	0.01	0.88
Hours per day spent on wage labor in agriculture—female	0.02	0.52
Sample size	**8,897**	

Source: Tanzania energy sector baseline household survey.

IGA = income generating activity, TZS = Tanzanian shillings.

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

Table B.3. FS impact analysis: Baseline equivalence of household characteristics

Household characteristics at baseline	Treatment mean	Control mean	Difference	*p*-value
Air conditioning/fan hours per month	0.62	0.68	-0.05	0.92
Any household member has a phone	0.76	0.7	0.06	0.13
Small batteries used per month	0.19	0	0.18	0.29
Annual expenditure on light bulbs (TZS)	1,331	3,719	-2,388	0.10
Monthly expenditure on candles (TZS)	549	190	359	0.23
Monthly amount of candles used (kg)	0.06	0.03	0.02	0.15
Amount of external pollution from carbon produced per month (kg CO_2)	276.3	292.69	-16.39	0.45
Monthly amount of charcoal used (kg)	37.54	36.06	1.48	0.82
Spending on cigarettes and alcohol in last 7 days (TZS)	1,272	1,240	32	0.91
Household moved in last 7.5 months	0.02	0.03	-0.01	0.14
Annual household consumption (TZS)	3,093,371	2,968,281	125,090	0.76
Cooking hours per month	208.42	198.17	10.25	0.31
Monthly amount of crop used by household (kg)	3.86	2.47	1.39	0.53
Light-hours per month	355.21	330.55	24.66	0.14
Current price of dry cell batteries (TZS)	945	633	313	0.14
Monthly amount of electricity from dry cell batteries (kWh)	0.1	0.1	0	0.79
Monthly expenditure on dry cell batteries (TZS)	4,110	3,329	781	0.32
Annual expenditure on electric appliances (TZS)	794	1,109	-315	0.73
Expenditure on electricity in last 30 days (TZS)	161	612	-451**	0.02
Annual expenditure on electricity (TZS)	25,703	21,215	4,488	0.80
Monthly amount of electricity from any source consumed by household (kWh)	44.79	22.45	22.34	0.54
Energy generation hours per month	42.87	24.22	18.65*	0.07
Annual household expenditure on energy (TZS)	216,480	176,713	39,767	0.29
Amount of electricity produced from generators and car batteries (kWh)	13.65	11.7	1.95	0.78
Amount of nonelectric energy produced from solid fuel, liquid fuel, and dry cell batteries (kWh)	803.4	840.36	-36.96	0.54
Monthly expenditure on nonelectric energy— farmer (TZS)	45,095	1,231	43,865	0.32
Household has flush toilet	0.03	0.05	-0.02*	0.10
Annual household food expenditure (TZS)	1,299,631	1,271,437	28,194	0.87
Fraction of household members female	0.52	0.51	0.01	0.58
Annual expenditure on solid, liquid, battery, and grid electricity (TZS)	36,282	31,548	4,734	0.41
Monthly amount of diesel used by household (liter)	2.06	2.01	0.05	0.94
Spending on grid electricity in last 30 days (TZS)	88	138	-50	0.38
Monthly amount of grid electricity used by household (kWh)	0.68	0.77	-0.09	0.81
Age of household head	44.35	45.19	-0.84	0.45
Household head married	0.75	0.74	0.01	0.74
Whether household head age 18 to 24	0.02	0.03	0	0.75
Heating hours per month	0	0.02	-0.02	0.29
Household had an adult member who suffered health problems	0.44	0.46	-0.02	0.77
Household head is female	0.25	0.23	0.03	0.21

Table B.3. (*continued*)

Household characteristics at baseline	Treatment mean	Control mean	Difference	*p*-value
Any household member age15 or older missed work in last 30 days due to illness	0.15	0.17	-0.02	0.13
Number of household members	5.13	5.02	0.11	0.46
Household received HIV information from television/radio/internet/telephone in last 30 days	0.62	0.62	-0.01	0.82
Value of home (TZS)	6,535,901	4,948,582	1,587,318	0.48
Household is electrifiable based on wall and roof material	0.79	0.79	0	0.96
Monthly IGA expenditure on electricity (TZS)	1,775	3,189	-1,414	0.29
Monthly IGA expenditure on nonelectric fuel (TZS)	58,915	6,617	52,298	0.24
Annual household income (TZS)	3,061,358	3,003,830	57,528	0.93
Fuel cost—kerosene (TZS)	2,652	2,775	-123	0.41
Monthly amount of kerosene used by household (liter)	4.53	5.15	-0.62	0.65
Household has any landline telephone	0	0	0**	0.04
Toilet type—latrine	0.07	0.06	0.01	0.63
Monthly amount of liquid fuel used by household for appliances (liter)	10.65	10.22	0.43	0.89
Monthly amount of LPG used by household (liter)	0.12	0.35	-0.23	0.45
Monthly amount of light consumed by household (lumen-hours)	78181.84	73946.02	4235.81	0.75
Monthly expenditure on nonelectric energy—manufacturing IGA (TZS)	2,920	1,427	1,493	0.54
Number of IGAs—manufacturing sector	0.07	0.08	-0.01	0.46
Number of IGAs—medical	0	0	0*	0.05
Annual medical expenses (TZS)	45,505	49,100	-3,596	0.51
Monthly expenditure on nonelectric energy— medical IGA (TZS)	0	8	-8	0.11
Household owns at least one mobile phone	0.76	0.7	0.06	0.13
Number of appliances owned by household	7.27	7.1	0.17	0.61
Number of children (under age 18) in household	2.65	2.57	0.08	0.51
Number of IGAs operated by household	1.05	1.01	0.04	0.64
Number of complete years lived in household	10.87	10.46	0.41	0.72
Water sources—river/lake/spring/pond/rain	0.38	0.33	0.06	0.61
Net income after adjusting for homeownership status	3,048,396	2,993,875	54,521	0.93
Household had no expenditure on food	0.04	0.05	-0.01	0.67
Toilet type—no toilet	0.01	0.02	0	0.59
Total household assets minus home value (TZS)	4,326,882	4,578,507	-251,625	0.78
Annual nonelectric energy expenditure (TZS)	191,761	155,775	35,986	0.19
Nonwage income (TZS)	1,100,909	1,015,699	85,210	0.62
Water sources—other	0.04	0.05	-0.01	0.67
Other household appliance hours per month	20.32	18.09	2.22	0.50
IGA at other location	0.72	0.76	-0.04	0.43
Toilet types—other	0.01	0.01	0	0.95
Other work tool, hours per month	22.64	19.49	3.15	0.68
Paid employee at IGA in last year	0.65	0.56	0.09	0.59
Household has indoor piped water during rainy and dry seasons	0.06	0.04	0.02	0.58
Toilet types—pit toilet	0.88	0.87	0.01	0.61
Monthly liquid fuel expenditure (TZS)	14,248	11,587	2,661	0.26
Monthly solid fuel expenditure (TZS)	15,734	14,741	994	0.72
Radio and CD hours per month	64.94	57.8	7.14	0.69
Refrigerator hours per month	11.69	12.34	-0.65	0.90

Table B.3. (*continued*)

Household characteristics at baseline	Treatment mean	Control mean	Difference	*p*-value
Household rents home	0.09	0.08	0.01	0.53
Annual rent (TZS)	8,313	7,957	355	0.86
Number of IGAs—repair shops and other IGAs	0.41	0.41	0.01	0.92
Monthly expenditure on nonelectric energy— repair and other IGA (TZS)	9,410	3,280	6,130	0.30
Roof of house is electrifiable	0.86	0.84	0.02	0.72
Annual expenditure on satellite dish and cable television (TZS)	1,489	14,540	-13,051**	0.04
Annual expenditure on school fees and supplies (TZS)	96,580	121,857	-25,277	0.42
Number of rooms household has for sleeping	2.72	2.71	0.02	0.87
Number of IGAs—small vendors	0.45	0.35	0.1*	0.10
Monthly expenditure on nonelectric energy— small vendor (TZS)	1,489	666	823	0.26
Hours per day spent on socializing— female	1.12	1.25	-0.13**	0.04
Annual expenditure on solar photovoltaic system (TZS)	16,069	10,434	5,636	0.43
Monthly amount of solid fuel used (kg)	90.9	86.98	3.92	0.36
Monthly amount of internal pollution from soot produced (g black carbon)	147.32	155.73	-8.41	0.53
Monthly amount of straw used (kg)	0	0.06	-0.06	0.13
Annual tax (TZS)	4,649	1,971	2,678	0.13
Total household assets (TZS)	10,862,782	9,527,089	1,335,693	0.61
Monthly total expenditure on solid and liquid fuel (TZS)	29,862	26,238	3,623	0.38
Monthly total electricity used (kWh)	817.73	852.83	-35.1	0.54
Family has male head, female spouse, no other adults	0.66	0.66	0	0.99
Transportation hours per month	198.06	177.05	21.01	0.32
IGA—truck or vendor	0.09	0.09	0.01	0.83
Hours per day spent on watching television—female	0.16	0.17	-0.01	0.88
Television hours per month	8.36	9.01	-0.64	0.86
IGA unpaid staff in last year	1.72	1.63	0.09	0.69
Water sources—water vendor, kiosk, water truck/tanker service	0.04	0.06	-0.02	0.53
Wall of house is electrifiable	0.88	0.89	-0.02	0.61
Fraction who have spoken to a ward development officer	0.14	0.14	0	0.98
Fuel cost—wood (TZS)	175	151	24	0.35
Monthly amount of wood used by household (kg)	100.01	111.56	-11.55	0.58
Number of years (including partial years) lived in household	11.03	10.6	0.43	0.71
Monthly amount of water from pumps (liter)	761.84	48274.86	-47513**	0.03
Water sources—outside dwelling	0.36	0.38	-0.02	0.85
Water pump hours per month	0.62	1.26	-0.65	0.28
Water sources—well and borehole	0.29	0.35	-0.06	0.44
Completed any education—key male	0.91	0.87	0.04	0.10
Household operates any IGA with grid electricity	0.05	0.05	-0.01	0.50
Assets of females if female head or spouse of head in home (TZS)	2,054,816	1,076,345	978,471	0.41
Assets of males if male head or spouse of head in home (TZS)	2,580,380	2,735,800	-155,419	0.77
Average age of IGA owners	40.15	39.57	0.59	0.50
Mobile phone monthly bill (TZS)	6,128	5,076	1,053	0.15
Charge mobile phone away from home	0.62	0.69	-0.07	0.19
Charge mobile phone at home or at neighbor’s house	0.38	0.31	0.07	0.19

Table B.3. (*continued*)

Household characteristics at baseline	Treatment mean	Control mean	Difference	*p*-value
Hours per day spent on taking care of children— female	0.77	0.82	-0.05	0.37
Highest grade completed—key female	5.49	5	0.49*	0.09
Highest grade completed—key male	6.66	6.18	0.49*	0.09
Hours per day spent on cooking and preparing food—female	3.1	3.04	0.06	0.75
Hours per day spent on resting during the day— female	1.38	1.4	-0.02	0.87
Average education (grade completed) of IGA owners	6.14	5.87	0.27	0.30
Number of electric protective devices (surge protectors, voltage stabilizers, regulators, and so forth)	0.01	0.03	-0.01	0.17
Hours per day spent on farming, gardening, poultry and livestock, animal grazing, fishing—female	2	2.17	-0.17	0.64
Number of IGAs—farmers	0.12	0.17	-0.04	0.28
Monthly expenditure on nonelectric energy— farm/small vendor IGA (TZS)	46,584	1,896	44,688	0.32
Hours per day spent on cooking, processing, and preparing food—female	3.24	3.23	0.01	0.96
Fraction of students age 5 to 24 who attend school with electricity	0.05	0.07	-0.02	0.30
Fraction of household members age 5 to 24 who attend school	0.58	0.58	0	0.88
Fraction of IGA—truck or vendor	0.41	0.39	0.02	0.55
Fraction of IGA—other location	0.52	0.54	-0.02	0.56
Hours per day spent collecting fuel—female	0.68	0.74	-0.06	0.71
Household member age 15 or older unable to work due to illness—female	0.12	0.13	-0.01	0.68
Household member age 15 or older unable to work due to illness— male	0.04	0.08	-0.03***	0.01
IGA at household	0.59	0.54	0.05	0.43
Total IGA energy expenditures (TZS)	60,686	9,797	50,889	0.25
Number of IGAs owned by females	0.7	0.61	0.09**	0.03
Monthly IGA income—top three IGAs only (TZS)	1,316,432	1,109,494	206,938	0.46
Monthly IGA income (TZS)	1,688,221	1,554,016	134,206	0.78
Number of IGAs owned by males	0.7	0.78	-0.08*	0.06
Total number of IGAs	1.4	1.39	0.01	0.83
Number of IGAs with electricity	0.07	0.09	-0.01	0.51
Number of IGAs using nonelectric energy	0.34	0.18	0.15**	0.03
Annual income—female (TZS)	1,143,970	1,022,447	121,524	0.48
Annual income—male (TZS)	2,350,251	2,342,486	7,766	0.99
Total telephone monthly bills—use plus charging (TZS)	9,347	8,107	1,239	0.17
Cost to recharge mobile phone (TZS)	184	167	17*	0.10
Multitasking hours—child	0.73	0.64	0.09	0.56
Multitasking hours—female	4.67	4.8	-0.13	0.83
Multitasking hours—male	2.28	2.25	0.03	0.92
Hours per day spent on sleeping at night—female	8.58	8.78	-0.19**	0.04
Hours per day spent on other household chores—female	2.14	2.22	-0.08	0.39
Hours per day spent on other IGAs—female	2.43	1.94	0.49	0.43
Hours per day spent on other leisure activities— female	0.62	0.65	-0.03	0.71
Other household activities—female	2.63	2.77	-0.15	0.29
Other household activities—male	2.05	2.2	-0.15	0.39
Hours per day spent on other time use—female	0.16	0.24	-0.08	0.16
Hours per day spent on personal hygiene—female	0.58	0.56	0.02	0.59

Table B.3. (*continued*)

Household characteristics at baseline	Treatment mean	Control mean	Difference	*p*-value
Completed primary education—key female	0.09	0.06	0.03*	0.06
Completed primary education—key male	0.14	0.12	0.03	0.34
Hours per day processing food—female	0.14	0.19	-0.05	0.23
Hours per day spent on listening to radio—female	1.75	1.64	0.11	0.50
Hours per day spent on reading and studying— female	0.13	0.13	0	0.91
Mobile phone recharge costs per week (TZS)	876	873	4	0.95
Hours per day spent on religious practices—female	0.59	0.64	-0.04	0.62
Hours per day spent on repairing clothes, basket, and so forth—female	0.19	0.22	-0.03	0.55
Hours per day at school—female	0.01	0.03	-0.02*	0.05
Completed secondary education—key female	0.05	0.04	0.01	0.48
Completed secondary education—key male	0.09	0.08	0.01	0.67
Hours per day spent on shopping—female	0.52	0.52	0	0.93
Hours per day spent on visiting neighbors or on other leisure activities—female	1.73	1.9	-0.17	0.14
Hours per day spent on visiting neighbors or on other leisure activities—male	2.66	2.86	-0.2	0.37
Hours per day spent on studying—female	0.13	0.15	-0.02	0.52
Hours per day spent on studying—male	0.44	0.38	0.06	0.59
Hours per day spent on taking meals—female	0.82	0.82	0	1.00
Completed tertiary education—key female	0.01	0	0.01	0.28
Completed tertiary education—key male	0.02	0.02	0	0.72
Hours per day spent on collecting water—female	0.9	1.01	-0.1	0.23
Average year IGA established	2002.4	2002.04	0.35	0.64
Hours spent per day on wage labor in nonagriculture—female	0.34	0.25	0.09	0.36
Hours per day spent on wage labor in agriculture—female	0.19	0.15	0.04	0.64
Sample size	**632**	**3,835**		

Source: Tanzania energy sector baseline household survey.

IGA = income generating activity.

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

Table B.4. Exploratory impact analysis of connection to the grid: Baseline equivalence of household characteristics

Household characteristics at baseline	Connection coefficient	*p*-value
Air conditioning/fan hours per month	**-1.16**	0.59
Any household member has a phone	-0.02	0.17
Small batteries used per month	0.03	0.49
Annual expenditure on light bulbs (TZS)	-89	0.99
Monthly expenditure on candles (TZS)	-288	0.60
Monthly amount of candles used (kg)	0.02	0.66
Amount of external pollution from carbon produced per month (kg CO_2)	-7.62	0.73
Monthly amount of charcoal used (kg)	0.99	0.85
Spending on cigarettes and alcohol in last 7 days (TZS)	-43	0.88
Household moved in last 7.5 months	-0.01	0.17
Annual household consumption (TZS)	-29,591	0.95
Cooking hours per month	-3.03	0.74
Monthly amount of crop used by household (kg)	-0.67	0.36
Light-hours per month	-30.37	0.25
Current price of dry cell batteries (TZS)	2	0.97
Monthly amount of electricity from dry cell batteries (kWh)	0	0.65
Monthly expenditure on dry cell batteries (TZS)	-28	0.94
Monthly amount of dung used (kg)	-0.23	0.29
Annual expenditure on electric appliances (TZS)	5,731	0.13
Expenditure on electricity in last 30 days (TZS)	-235	0.72
Annual expenditure on electricity (TZS)	19,349	0.11
Monthly amount of electricity from any source consumed by household (kWh)	124.54	0.11
Energy generation hours per month	-7.7	0.61
Annual household expenditure on energy (TZS)	29,375	0.21
Amount of electricity produced from generators and car batteries (kWh)	6.37	0.29
Amount of nonelectric energy produced from solid fuel, liquid fuel, and dry cell batteries (kWh)	-35.62	0.56
Monthly expenditure on nonelectric energy—farmer (TZS)	7,079	0.24
Household has flush toilet	-0.03	0.22
Annual household food expenditure (TZS)	-11,585	0.94
Fraction of household members female	-0.01	0.18
Annual expenditure on solid, liquid, battery, and grid electricity (TZS)	1,643	0.82
Monthly amount of diesel used by household (liter)	-0.13	0.95
Spending on grid electricity in last 30 days (TZS)	153	0.32
Monthly amount of grid electricity used by household (kWh)	0.68	0.40
Age of household head	-1.73***	0.01
Household head married	-0.02	0.47
Household head age 18 to 24	0.01**	0.01
Heating hours per month	0.07	0.85
Household had an adult member who suffered health problems	-0.05	0.11
Household head is female	0	0.89
Any household member age 15 or older missed work in last 30 days due to illness	-0.03**	0.03
Number of household members	0.05	0.72
Household received HIV information from television/radio/internet/telephone in last 30 days	-0.06**	0.01

Table B.4. (*continued*)

Household characteristics at baseline	Connection coefficient	*p*-value
Value of home (TZS)	2,510,265	0.34
Household is electrifiable based on wall and roof material	0.03*	0.08
Monthly IGA expenditure on electricity (TZS)	9,706	0.17
Monthly IGA expenditure on nonelectric fuel (TZS)	-7,266	0.73
Annual household income (TZS)	-889,915	0.37
Fuel cost—kerosene (TZS)	-387**	0.02
Monthly amount of kerosene used by household (liter)	1.25	0.46
Household has any landline telephone	0	0.54
Toilet type—latrine	0.02	0.45
Monthly amount of liquid fuel used by household for appliances (liter)	6.32	0.14
Monthly amount of LPG used by household (liter)	-0.56	0.48
Monthly amount of light consumed by household (lumen-hours)	-17718.3	0.34
Monthly expenditure on nonelectric energy—manufacturing IGA (TZS)	757	0.44
Number of IGAs—manufacturing sector	0	0.78
Number of IGAs—medical	0	0.56
Annual medical expenses (TZS)	-15,160	0.19
Monthly expenditure on nonelectric energy—medical IGA (TZS)	-1	0.79
Household owns at least one mobile phone	-0.01	0.18
Number of appliances owned by household	-0.14	0.78
Number of children (under age 18) in household	0.06	0.53
Number of IGAs operated by household	-0.05	0.51
Number of complete years lived in household	-0.05	0.94
Water sources—river/lake/spring/pond/rain	0	0.99
Net income after adjusting for homeownership status (TZS)	-892,417	0.37
Household had no expenditure on food	0.01	0.27
Toilet type—no toilet	0	0.91
Total household assets minus home value (TZS)	-1,078,818	0.46
Annual nonelectric energy expenditure (TZS)	9,160	0.65
Nonwage income (TZS)	-849,137**	0.02
Water sources—other	0.02	0.13
Other household appliance hours per month	-2.47	0.63
IGA at other location	-0.02	0.62
Toilet types—other	0	0.35
Other work tool, hours per month	-2.38	0.78
Paid employee at IGA in last year	-0.02	0.93
Household has indoor piped water during rainy and dry seasons	-0.01	0.62
Toilet types—pit toilet	0.01	0.71
Monthly liquid fuel expenditure (TZS)	-3,548	0.55
Monthly solid fuel expenditure (TZS)	3,693	0.34
Radio and CD hours per month	-4.58	0.71
Refrigerator hours per month	15.26	0.32
Household rents home	0	0.87
Annual rent (TZS)	1,937	0.43
Number of IGAs—repair shops and other IGAs	0.01	0.78
Monthly expenditure on nonelectric energy—repair and other IGA (TZS)	-14,565	0.45
Roof of house is electrifiable	0	0.72
Annual expenditure on satellite dish and cable television (TZS)	25,209	0.19
Annual expenditure on school fees and supplies (TZS)	-177,266	0.15

Table B.4. (*continued*)

Household characteristics at baseline	Connection coefficient	*p*-value
Number of rooms household has for sleeping	-0.15	0.11
Number of IGAs—small vendors	-0.01	0.84
Monthly expenditure on nonelectric energy—small vendor (TZS)	-522	0.81
Hours per day spent on socializing—female	-0.11	0.20
Annual expenditure on solar photovoltaic system (TZS)	7,465	0.47
Monthly amount of solid fuel used (kg)	-0.69	0.87
Monthly amount of internal pollution from soot produced (g black carbon)	-7.4	0.71
Monthly amount of straw used (kg)	-0.16	0.37
Annual tax (TZS)	585	0.89
Total household assets (TZS)	1,431,666	0.67
Monthly total expenditure on solid and liquid fuel (TZS)	209	0.98
Monthly total electricity used (kWh)	-28.32	0.65
Family has male head, female spouse, no other adults	-0.03	0.28
Transportation hours per month	-14.18	0.72
IGA—truck or vendor	-0.02	0.14
Hours per day spent on watching television—female	0.06	0.44
Television hours per month	5.21	0.33
IGA unpaid staff in last year	0.12	0.71
Water sources—water vendor, kiosk, water truck/tanker service	0.03	0.42
Wall of house is electrifiable	0.04**	0.04
Fraction who have spoken to a ward development officer	0.06***	0.00
Fuel cost—wood (TZS)	0	0.99
Monthly amount of wood used by household (kg)	-9.76	0.49
Number of years (including partial years) lived in household	-0.06	0.93
Monthly amount of water from pumps (liter)	110384.7	0.11
Water sources—outside dwelling	-0.07	0.23
Water pump hours per month	1.19	0.36
Water sources—well and borehole	0.07	0.16
Completed any education—key male	0	0.85
Household operates any IGA with grid electricity	0	0.91
Assets of females if female head or spouse of head in home (TZS)	2,627,122	0.27
Assets of males if male head or spouse of head in home (TZS)	-594,390	0.51
Average age of IGA owners	-0.89	0.12
Mobile phone monthly bill (TZS)	478	0.41
Charge mobile phone away from home	-0.02	0.52
Charge mobile phone at home or at neighbor's house	0.02	0.52
Hours per day spent on taking care of children—female	0.03	0.63
Highest grade completed—key female	-0.23	0.30
Highest grade completed—key male	0.05	0.82
Hours per day spent on cooking and preparing food—female	0.03	0.82
Hours per day spent on resting during the day—female	-0.02	0.77
Average education (grade completed) of IGA owners	0.15	0.46
Number of electric protective devices (surge protectors, voltage stabilizers, regulators, and so forth)	0.02	0.48
Hours per day spent on farming, gardening, poultry and livestock, animal grazing, fishing—female	0.17	0.35
Number of IGAs—farmers	-0.05	0.11
Monthly expenditure on nonelectric energy—farm/small vendor IGA (TZS)	6,557	0.30

Table B.4. (*continued*)

Household characteristics at baseline	Connection coefficient	*p*-value
Hours per day spent on cooking, processing, and preparing food— female	-0.01	0.94
Fraction of students age 5 to 24 who attend school with electricity	-0.01	0.74
Fraction of household members age 5 to 24 who attend school	-0.02	0.17
Fraction of IGA—truck or vendor	0.01	0.66
Fraction of IGA—other location	0	0.90
Hours per day spent on collecting fuel—female	-0.05	0.40
Household member age 15 or older unable to work due to illness— female	-0.03**	0.02
Household member age 15 or older unable to work due to illness—male	-0.01	0.39
IGA at household	0	0.97
Total IGA energy expenditures (TZS)	2,452	0.91
Number of IGAs owned by females	-0.04	0.18
Monthly IGA income—top three IGAs only (TZS)	-208,279	0.75
Monthly IGA income (TZS)	-235,997	0.73
Number of IGAs owned by males	0	0.98
Total number of IGAs	-0.05	0.34
Number of IGAs with electricity	0.02	0.64
Number of IGAs using nonelectric energy	0.07*	0.09
Annual income—female (TZS)	-625,246	0.23
Annual income—male (TZS)	343,373	0.54
Total phone monthly bills—use plus charging (TZS)	874	0.22
Cost to recharge mobile phone (TZS)	6	0.39
Multitasking hours—child	0.03	0.78
Multitasking hours—female	-0.5	0.14
Multitasking hours—male	-0.18	0.53
Hours per day spent on sleeping at night—female	-0.06	0.39
Hours per day spent on other household chores—female	-0.08	0.35
Hours per day spent on other IGAs—female	0.08	0.72
Hours per day spent on other leisure activities—female	-0.06	0.26
Other household activities—female	-0.14	0.26
Other household activities—male	-0.17	0.18
Hours per day on other time use—female	-0.01	0.85
Hours per day spent on personal hygiene—female	-0.06	0.11
Completed primary education—key female	0	0.91
Completed primary education—key male	-0.03	0.38
Hours per day spent on processing food—female	-0.04	0.29
Hours per day spent on listening to radio—female	-0.01	0.96
Hours per day spent on reading and studying—female	0	0.94
Mobile phone recharge costs per week (TZS)	89	0.22
Hours per day spent on religious practices—female	-0.09	0.13
Hours per day spent on repairing clothes, basket, and so forth— female	-0.03	0.58
Hours per day at school—female	-0.04	0.29
Completed secondary education—key female	-0.01	0.51
Completed secondary education—key male	-0.01	0.86
Hours per day spent on shopping—female	-0.01	0.90
Hours per day spent on visiting neighbors or on other leisure activities— female	-0.17	0.14
Hours per day spent on visiting neighbors or on other leisure activities— male	-0.06	0.70
Hours per day spent on studying—female	-0.05	0.39
Hours per day spent on studying—male	-0.01	0.96
Hours per day spent on taking meals—female	-0.05	0.17

Table B.4. (*continued*)

Household characteristics at baseline	Connection coefficient	*p*-value
Completed tertiary education—key female	0	0.81
Completed tertiary education—key male	0.03*	0.07
Hours per day spent on collecting water—female	-0.01	0.89
Average year IGA established	1.07**	0.02
Hours per day spent on wage labor in nonagriculture—female	-0.07	0.63
Hours per day spent on wage labor in agriculture—female	-0.01	0.72
Sample size	**8,818**	

Source: Tanzania energy sector baseline household survey.

IGA = income generating activity, TZS = Tanzanian shillings.

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

APPENDIX C

OUTCOME DEFINITIONS

This page has been left blank for double-sided copying.

In this appendix we provide detailed descriptions of the community-level variables (Table C.1), the household-level variables (Table C.2), and the control variables (Table C.3). We also provide a table with a list of the outcome variables for which we lacked a baseline measure (Table C.4). That table also includes the proxy we had for one of those variables. Unless stated otherwise all variables covered by Table C.1 are based on the community follow-up survey and all variables in Table C.2 are based on the household follow-up survey. All control variables were measured at baseline and unless stated otherwise are based on the household baseline survey.

Table C.1. Full descriptions of community outcomes

Short description	Complete description
Connection Rates	
Primary	
Fraction of households connected to the grid based on the community survey response.	Fraction of households connected to the grid, calculated based on the approximate number of households the community survey respondent reported being connected to the main grid or main power line.
Secondary	
Fraction of households connected to the national grid based on household listing	Fraction of households connected to the grid, based on individual household status, as reported by the community representatives in the household listing.
Fraction of households within 30m of the grid based on household listing	Fraction of households within 30m of the grid, based on individual household status, as reported by the community representatives in the household listing.
Community has access to	Indicates that any household in the village/*mtaa* has access to electricity from _______, according to the community survey respondent.
National grid	National grid
Isolated grid	Isolated grid power system
Generator	Generator
Solar, windmill, and other electricity sources	Solar, windmill, and other electricity sources
Energy use	
Secondary	
TANESCO informed households fully about low tariff requirements	Indicates whether households in the community were informed *both* that (1) in order to qualify for the lowest possible tariff they must consume little electricity *and* (2) they have to pay the regular tariff and monthly service charge for a few months in order to qualify for the low tariff.
TANESCO informed households partially about low tariff requirements	Indicates whether households in the community were informed *either* that (1) in order to qualify for the lowest possible tariff they must consume little electricity *or* (2) they have to pay the regular tariff and monthly service charge for a few months in order to qualify for the low tariff.
Community has access to kerosene	Indicates whether there is any place in the community to purchase kerosene, as reported by the community survey respondent.
Community has access to diesel/gasoline	Indicates whether there is any place in the community to purchase diesel/gasoline, as reported by the community survey respondent.
Community has access to firewood, charcoal, or dung	Indicates whether there is any place in the community to purchase firewood, charcoal, or dung, as reported by the community survey respondent.

Table C.1. (*continued*)

Short description	Complete description
Education and child time use	
Primary	
Community has electrified school(s)	Indicates whether the community has an electrified school
Secondary	
Distance from community to nearest preprimary school	Distance to nearest pre-primary school as reported by the community survey respondent (in km)
Distance from community to nearest primary school	Distance to nearest primary school as reported by the community survey respondent (in km)
Distance from community to nearest secondary school	Distance to nearest secondary school as reported by the community survey respondent (in km)
Health and safety	
Primary	
Community has electrified health facility	Indicates whether the community has any electrified health facility (dispensary, health center, diagnostic laboratory, hospital), as reported by the community survey respondent.
Secondary	
Community has a health facility open at night	Indicates whether the community has any health facility that is open at night (is open 24 hours or closes later than 6:00PM), as reported by the community survey respondent.
Distance from community to nearest health facility (km)	Distance to nearest health facility, as reported by the community survey respondent (in km).
Distance from community to obtain vaccination service	Distance to nearest place to obtain a vaccination, as reported by the community survey respondent (in km).
Distance from community to obtain x-ray service	Distance to nearest place to obtain an x-ray, as reported by the community survey respondent (in km).
Distance from community to obtain malaria test	Distance to nearest place to obtain a malaria test, as reported by the community survey respondent (in km).
Distance from community to obtain HIV test	Distance to nearest place to obtain an HIV test, as reported by the community survey respondent (in km).
Perception of female residents' safety at night – feel very safe	Indicates that the community survey respondent thinks that female residents feel very safe at night.
Perception of female residents' safety at night – feel somewhat safe	Indicates that the community survey respondent thinks that female residents feel somewhat safe at night.
Perception of female residents' safety at night – feel very unsafe	Indicates that the community survey respondent thinks that female residents feel very unsafe at night.
Perception of male residents' safety night – feel very safe	Indicates that the community survey respondent thinks that male residents feel very safe at night.
Perception of male residents' safety night – feel somewhat safe	Indicates that the community survey respondent thinks that male residents feel somewhat safe at night.
Perception of male residents' safety night – feel very unsafe	Indicates that the community survey respondent thinks that male residents feel very unsafe at night.
Most community members have piped water	Indicates that most people in the community get their water from a piped water source, according to the community survey respondent.
Community has a police post	Indicates whether the community has a police post, according to the community survey respondent.

Table C.1. (*continued*)

Short description	Complete description
Business and adult time use	
Primary	
Community has at least one electrified business	Indicates whether the community has at least one electrified business, according to the community survey respondent.
Secondary	
Community has an electrified repair shop	Indicates whether the community has an electrified repair shop (for agricultural tool or cars, motorcycles, and bicycles), according to the community survey respondent.
Community has an electrified tea/coffee shop, guest house, or hotel	Indicates whether the community has an electrified tea/coffee shop, guest house, or hotel based on the community survey respondent.
Community has other electrified businesses	Indicates whether the community has an electrified business not listed above based on the community survey respondent.
Fraction of establishments in community that are electrified	Approximate fraction of __________ currently operating in the community that use grid electricity, according to the community survey respondent.
All businesses	All businesses
Weekly markets	Weekly markets
Agricultural repair shops	Agricultural repair shops
Vehicle repair shops	Vehicle repair shops
Restaurants, tea/coffee shops	Restaurants, tea/coffee shops
Telephone repair shops	Telephone repair shops
Carpentry shops	Carpentry shops
Hotels/guest houses	Hotels/guest houses
Hair salons/barber shops	Hair salons/barber shops
Tailor shops	Tailor shops
Newspaper shops	Newspaper shops
Cafes	Cafes
Grain mills	Grain mills
Saw mills	Saw mills
Oil mills	Oil mills
Mobile money banking	Mobile money banking
Welding and metal fabrication	Welding and metal fabrication
Car battery charging shops	Car battery charging shops
Community has an electrified post office	Indicates whether the community has an electrified post office, according to the community survey respondent.
Community has farming, fishing, livestock, or hunting as main source of income	Indicates whether the main source of income in the community is farming, fishing, livestock, or hunting, according to the community survey respondent.

Table C.1. (*continued*)

Short description	Complete description
Economic well-being	
Primary	
Natural log of price per acre of residential land in community	Natural log of the price per acre of residential land in the community, according to the community survey respondent.
Secondary	
Natural log of price per acre of farmland in community	Natural log price per acre of farming land in the community, according to the community survey respondent.
Community is one in which most people have mobile phones	Indicates whether almost all people in the community have a mobile phone, according to the community survey respondent.
Community is one with a new ______built after 2011	Indicates whether community has a ___________ built since 2011, according to the community survey respondent.
School	School
Public water supply	Public water supply
Health center	Health center
Roads	Roads
Community has plans within two years for new or upgraded	Indicates whether community has a new _________planned in the next two years, according to the community survey respondent.
School	School
Public water supply	Public water supply
Health center	Health center
Roads	Roads
Market	Market
Composition and mobility	
Primary	
Number of households in community based on household listing	Number of households in community as reported by the community representative in the household listing.
Secondary	
Fraction of households in community at follow-up that are in-migrants since 2011 based on the household listing	Fraction of households in community who were listed as being in-migrants since 2011 in the household listing.
Fraction of households in community at follow-up that are newly formed since 2011 based on the household listing	Fraction of households in community who were listed as being newly formed households since 2011 in the household listing
Community is identified as *mtaa* – urban	Indicates whether a community is considered urban, as reported by the community survey respondent.
Community boundaries changed since 2011	Indicates whether a community has different boundaries than it did in 2011, as reported by the community survey respondent.

Table C.2. Full descriptions of household outcomes

Short description	Complete description
Connection rates	
Primary	
Household is connected to national grid	Indicates that the household is connected to the national grid.
Secondary	
Household is connected to MCC line	Indicates that the household is connected to an MCC line based on the follow-up household survey and the type of pole closest to the home based on the pole data.
Household is connected to non-MCC lines built after 2011[a]	Indicates that the household is connected to a non-MCC line built after October 2011 based on same data as previous variable.
Household is connected to non-MCC lines built before 2011	Indicates that the household is connected to a non-MCC line built before October 2011 based on same data as previous variable.
Household has access to grid without additional poles	Indicates that the household can connect to the grid without purchasing additional poles.
Household is within 30/40/50/100 meters of nearest electric pole (GPS data)	Indicates that the household is within 30/40/50/100 meters of an electrical pole at follow-up, based on household and pole GPS coordinates.
Household is within 30/40/50/100 meters of nearest electric pole (Survey data)	Indicates that the household is within 30/40/50/100 meters of an electrical pole.
Household is within 30 meters of nearest electric pole (Listing data)	Indicates that the household is within 30 meters of an existing line at follow-up, as reported by the community representative in the follow-up household listing.
Average years household has been connected to national grid	Number of years household has been connected to the national grid.
Average hours per day household has grid electricity	Average number of hours per day the household has grid electricity.
Energy use	
Primary	
Monthly amount of electricity used by household from any source (kWh)	Monthly amount of electricity (in kwh) the household produces from any source (generators, car batteries, dry cell batteries, and grid electricity), as reported by the household in the follow-up household survey.
Monthly amount of liquid fuel used by household (liter)	Monthly amount (in L) of liquid fuel (kerosene, diesel/gasoline, LPG) used by the household.
Secondary	
Monthly hours of electric fan used by household	Monthly number of hours an electric fan is used by the household.
Household owns a generator	Indicates that the household owns a generator (liquid fuel, solar, hydro or wind).
Monthly amount of kerosene used by household (liter)	Monthly amount of kerosene used by the household.
Household owns a television	Indicates that the household owns at least one TV.

Table C.2. (*continued*)

Short description	Complete description
Household uses electricity from any source except batteries	Indicates that the household uses electricity from any source other than batteries.
Monthly hours of electric tools/appliances used by household	Monthly number of hours electric tools and appliances are used by the household.
Monthly amount of grid electricity used by household (kwh)	Monthly amount of electricity (in kwh) the household produces from the grid, calculated based on the follow-up survey.
Monthly amount of light consumed by household (lumen-hours)	Monthly amount of light (in lumen-hours) consumed by the household based on average daily use of light-producing devices.
Total monthly cost of light consumed by household (TZS)[b]	Total monthly cost of light in the household (TZS) based on average daily use of light-producing devices as reported by the household in the follow-up survey and the average cost per kwh of grid electricity calculated by the authors.
Household owns at least one mobile phone	Indicates that the household owns at least one mobile phone.
Number of electric tools/appliances owned by household	Number of electric tools and appliances owned by the household.
Monthly amount of nongrid electricity used by household (kwh)	Amount of non-grid electricity used by the household (kWh).
Monthly household costs for mobile phone recharge (TZS)	Monthly mobile phone recharge cost (TZS) for the household.
Monthly amount of solid fuel used by household (kg)	Monthly amount of solid fuel (wood, crops, straw, dung, charcoal, and candles) (kg) used by the household.
Education and child use	
Primary	
Average hours per day children (age 5 to 14) spend studying at night[c]	Average hours per day all children aged 5-14 years in the household spend studying at night.
Secondary	
Average hours per day children (age 5 to 14) spend in total studying	Average hours per day all children aged 5-14 years in the household spend studying.
Average hours per day youth (age 15 to 24) spend studying at night	Average hours per day all youth aged 15-24 years in the household spend studying at night.
Average hours per day youth (age 15 to 24) spend in total studying	Average hours per day all youth aged 15-24 years in the household spend studying.
Hours children (age 5 to 14) spent in last 24 hours watching television	Hours children aged 5-14 years spent watching TV in the last 24 hours, as reported by the household survey respondent at follow-up.

Table C.2. (*continued*)

Short description	Complete description
Hours children (age 5 to 14) spent in last 24 hours collecting water and fuel	Hours children aged 5-14 years spent on collecting water and fuel in the last 24 hours.
Hours children (age 5 to 14) spent in last 24 hours on leisure/entertainment	Hours children aged 5-14 spent on leisure/entertainment in the last 24 hours.
Hours children (age 5 to 14) spent in last 24 hours sleeping at night	Hours children aged 5-14 spent sleeping at night in the last 24 hours.
Hours children (age 5 to 14) spent in last 24 hours performing other household chores	Hours children aged 5-14 spent doing other household chores in the last 24 hours as reported by the household in the follow-up survey.
Fraction of children in household age 5 to 14 attending school	Indicates that the household has a child aged 5-14 years in the household attending school.
Household has any child age 5 to 14 attending a school with electricity	Indicates that the household has any child aged 5-14 years in an electrified school as reported by the household in the follow-up survey.
Health and Safety	
Primary	
Fraction of youth aged 15 to 24 in the household with health problems in last 7 days	Fraction of youth aged 15-24 in the household with health problems (respiratory issues; vision problems; headaches) in the last 7 days.
Fraction of children aged 5 to 14 in the household with health problems in last 7 days	Fraction of youth aged 5-14 in the household with health problems (respiratory issues; vision problems; headaches) in the last 7 days.
Secondary	
Household has a member age 15 to 24 who missed work in the last 30 days due to illness	Indicates that any adult aged 15-24 in the household missed work in the last 30 days due to illness.
Monthly amount of internal pollution from soot (grams of black carbon)	Amount of internal pollution from soot produced per month (grams of black carbon) based on household's solid fuel, liquid fuel, and grid electricity use, as reported in the follow-up household survey, and the authors' calculations.
Monthly amount of external pollution from carbon (kg CO2)	Amount of external pollution from carbon produced per month (kg CO2) based on household's solid fuel, liquid fuel, and grid electricity use, as reported in the follow-up household survey, and the authors' calculations.
Household survey respondent has received family planning information from television/radio/internet/telephone in last 30 days	Indicates that the household received family planning info from TV, radio, internet, or phone over the last 30 days.
Household survey respondent currently uses family planning method	Respondent currently uses family planning methods, as reported in the follow-up survey.

Table C.2. (*continued*)

Short description	Complete description
Household survey respondent has received HIV information from media in last 30 days	Indicates that the household received HIV info from television, radio, internet, or phone in last 30 days.
Household whose last hospital visited had grid electricity at night	Indicates that the last hospital a household visited had grid electricity at night. Set to 0 if never visited a hospital at night either for self, a family member, or a friend.
Respondent feels safe at night by all measures of safety	Indicates that the respondent feels safe, by all measures (enough light to walk at night, feel safe walking at night, lights provide protection against crime, lights provide protection against wild animals).
Respondent feels safe at night by at least one measure of safety	Indicates that the respondent feels safe, by at least one measure (enough light to walk at night, feel safe walking at night, lights provide protection against crime, lights provide protection against wild animals).
Respondent feels safe at night by more than half the measures of safety	Indicates that the respondent feels safe, by more than half the measures (enough light to walk at night, feel safe walking at night, lights provide protection against crime, lights provide protection against wild animals).
Household had a major fire in home since 2011	Indicates that the household had a major fire since 2011.
Household had a fire caused by electric source since 2011	Indicates that the household had a major fire that was caused by electric source since 2011.
Household had a fire caused by nonelectric source since 2011	Indicates that the household had a major fire that was caused by a non-electric source since 2011.
Business and adult time use	
Primary	
Household operates any IGA	Indicates that the household operates at least one IGA.
Secondary	
Household operates any IGA that uses grid electricity	Indicates that the household operates any IGA that uses grid electricity.
Household's monthly revenue from IGA (TZS)	The household’s monthly revenue from IGAs.
Household's annual revenue from IGA (TZS)	The household’s yearly revenue from IGAs.
Household has at least one member who is a paid employee	Indicates that the household has at least one member age 15 or over who is a paid employee (wage labor or salaried employee).
Women's/men’s time use: Hours per day on each type of activity	*As reported by a female respondent (for female time use) and by a female or male respondent (for male time use) in the follow-up household survey, the number of hours the female/male spent on these activities in the past 24 hours:*
Wage labor (agricultural and nonagricultural)	Agricultural and nonagricultural wage labor
Nonwage labor/other productive activities (farming and other activities)	Nonwage labor and other productive activities such as farming, kitchen gardening, poultry and livestock raising, animal grazing, and fishing

Table C.2. (*continued*)

Short description	Complete description
Other IGA	Other income-generating activities such as tending shop, doing handicrafts in the past 24 hours
Household chores and child care	Household chores such as washing clothes, household cleaning, and cleaning dishes; and caring for children (bathing, feeding, dressing)
Collecting fuel and water	Water and fuel collection
Cooking, processing, and preparing food	Cooking and preparing meals; food processing
Reading and studying	Reading and studying
Socializing and resting	Taking meals; listening to the radio; watching television; other leisure and entertainment activities; resting/napping during the day; visiting neighbors/socializing/entertaining guests; shopping; getting news from the newspaper, radio, or television.
Time spent at home with family	Time spent at home with family
Watching television	Watching television
Sleeping at night	Sleeping at night
Economic well-being	
Primary	
Annual household nonelectricity consumption (TZS)	Total household non-electricity consumption (TZS) in the last year, summed across multiple consumption categories reported by the household in the follow-up survey.
Secondary	
Annual household income (TZS)	Total household annual income (TZS).
Household per capita total daily consumption (TZS)	Household per capita daily consumption (TZS).
Household per capita daily income (TZS)	Household's per capita daily income (TZS) (wage income, non-wage income, and IGA income).
Household consumes less than $1 per day per person	Indicates that the household lives on less than $1 per day, per person based on total annual household consumption calculated from follow-up survey responses.
Household consumes less than $2 per day per person	Indicates that the household lives on less than $2 per day, per person based on total annual household consumption calculated from follow-up survey responses.
Total household assets (TZS)	Total household assets (TZS) (value of home, land, livestock/poultry, savings/deposits/investments, and valuables/cash minus value of debt).
Household lives in an electrifiable dwelling based on wall and roof materials	Indicates the dwelling is considered electrifiable, that is the walls and roof are constructed of a material other than grass or mud.
Number of rooms in household for sleeping	Number of rooms the household has for sleeping.
Household has a flush toilet	Indicates that the household has a flush toilet.
Household has piped water in rainy and dry seasons	Indicates that the household has indoor piped water during both the rainy and dry seasons.

Table C.2. (*continued*)

Short description	Complete description
Composition and mobility	
Primary	
Household moved within community since 2011	Indicates that a household remains in the same community as at baseline but has moved within that community since 2011.
Household out-migrated since 2011	Indicates that a household has moved out of the community they resided in at baseline, as reported by a community representative in the follow-up household listing.
Household out-migrated since 2011 (among those with baseline income above district median)	Indicates that a household has moved out of the community they resided in at baseline, as reported by community representative in the follow-up household listing, and had a baseline income above the district median, as calculated based on the baseline household survey.
Household out-migrated since 2011 (among those with baseline income below district median)	Indicates that a household has moved out of the community they resided in at baseline, as reported by community representative in the follow-up household listing, and had a baseline income below the district median, as calculated based on the baseline household survey.

[a] The survey instrument on poles specified "before October 2011" or "after October 2011", which implies that it was not clear what response should be given for poles built in the month of October 2011. It appears to us that in general the respondents chose arbitrarily in those cases rather than leaving the entry blank.

[b] More precisely, the total monthly cost of light is calculated as the sum of the monthly cost of three different sources of light: electric lighting, kerosene lanterns, and candles. The monthly cost of electric lighting is the average kWh used per month for lights times the cost of grid electricity per kWh, as calculated by the authors based on total expenditures on electricity and the tariffs being charged by TANESCO at that time. The monthly cost of lanterns is the average number of liters of kerosene consumed per month from lanterns times the average cost per liter of kerosene as reported by the household. The monthly cost of candles is the number of candles used per month times the average market price of a candle as reported by the household.

[c] Parents were asked how many hours per day each child spends studying during the day and at night, and these numbers were averaged across all children of that age in the household. For other activities, parents were simply asked how much time one specific child age 5-14 spent on that activity during the past 24 hours.

Table C.3. Full descriptions of control variables

Short description	Complete description
Household-level controls	
Age of household head	Age of the household head, in years
Household head is female	Indicates that the household head is female
Household head is single	Indicates that the household head is single/not married
Household head is divorced	Indicates that the household head is divorced/separated
Household head is widowed	Indicates that the household head is widowed
Household head education: none	Indicates that the household head has never attended school
Household head education: secondary or higher	Indicates that the household head has completed secondary school or higher
Household size	Total number of members in the household
Per capita daily income	Average daily income in the household, per person
Amount of electricity consumed	Amount of electricity consumed by household from any source monthly (kwh)
Community-level controls	
Community is identified as *mtaa* – urban	Indicates whether a community is considered urban, as reported by the community survey respondent.
Number of households in community	Number of households in community as reported by the community representative in the household listing.
Percentage of households connected	Percent of total households in community that are connected, as reported by the community representative in the household listing.
Number of eligible households	Number of households in the community eligible for the T&D lines evaluation
Community is connected, baseline	Indicates that community has at least one connected household, as reported by the community representative in the household listing.
Average household income, baseline	Average annual household income
Community has weekly market[a]	Indicates that community has weekly market, as reported in the community survey
Community has paved road[a]	Indicates that community is accessible by paved road, as reported in the community survey
Community has public water supply project[a]	Indicates that community had a public water supply project in the past two years, as reported in the community survey
Controls based on matching, T&D lines analysis	
Candle use	Amount of candles (kg) used by household monthly
Grid expenditures	Amount spent on grid electricity in last 30 days (TZS)
Amount of grid electricity used	Amount of electricity household produces from grid monthly (kwh)
Adult missed work due to illness	Indicates that household has any adult 15 or older who missed work in last 30 days due to illness
Household water source: other	Indicates that household's water comes from a source other than piped water, borehole, water vendor or truck, or nature.
Size of home	Number of rooms household has for sleeping

Table C.3. (*continued*)

Short description	Complete description
Household has spoken to a ward development officer	Indicates that household has ever talked to a member of the local Development Committee or the local Community Development Officer regarding a project that educates women on the benefits of having electricity in their homes.
Household water source: borehole	Indicates that household's water comes from a borehole
Adult female missed work due to illness	Indicates that household has a female 15 years or older who missed work in last 30 days due to illness.
Number of female-owned IGAs	Number of IGAs owned by females in the household
Number of total IGAs	Number of total IGAs owned by the household
Time spent on other household activities: female	Number of hours female respondent spent on other household activities in the last 24 hours
Time spent on shopping: female	Number of hours female respondent spent on shopping in the last 24 hours
Average year IGA was established	Average year in which household IGAs were established
Controls based on matching, FS Analysis	
Amount spent on electricity	Amount household spent on electricity in the last 30 days (TZS)
Household has a landline phone	Indicates that household owns a landline phone
Annual spending on satellite dish and cable TV	Total annual household spending on satellite dish and cable TV (TZS)
Time spent on socializing: female	Number of hours female respondent spent socializing in the last 24 hours
Water consumption from pumps	Amount of water (L) produced by household from pumps
Adult male missed work due to illness	Indicates that household has a male 15 years or older who missed work in last 30 days due to illness.
Number of female-owned IGAs	Number of IGAs owned by females in the household
Number of non-electric IGAs	Number of IGAs owned household that do not use electricity
Time spent on sleep: female	Number of hours female respondent spent sleeping at night in the last 24 hours
Controls based on matching, Exploratory Analysis	
Household head is 18-24 years old	Indicates that the household head is 18-24 years old
Adult missed work due to illness	Indicates that household has any adult 15 or older who missed work in last 30 days due to illness
Household received HIV/AIDS information	Household received HIV information from TV/radio/internet/phone in last 30 days
Average kerosene cost	Average cost to household of a liter of kerosene (TZS)
Annual non-wage income	Total annual household non-wage income (TZS)
Household has spoken to a ward development officer	Indicates that household has ever talked to a member of the local Development Committee or the local Community Development Officer regarding a project that educates women on the benefits of having electricity in their homes.
Adult female missed work due to illness	Indicates that household has a female 15 years or older who missed work in last 30 days due to illness.
Average year IGA was established	Average year in which household IGAs were established

[a] These variables were controls only in the exploratory analysis of the impact of being connected to the grid.

Table C.4. Outcomes without a lagged (baseline) measure

Follow-up outcome	Proxy for lagged outcome
Household is connected to MCC lines	None
Household is connected to non-MCC lines built after 2011	None
Household is connected to non-MCC lines built before 2011	None
Household is within	None
30 meters of nearest electric pole (GPS data)	None
30 meters of nearest electric pole (household survey data)	None
40 meters of nearest electric pole (GPS data)	None
40 meters of nearest electric pole (household survey data)	None
50 meters of nearest electric pole (GPS data)	None
50 meters of nearest electric pole (household survey data)	None
100 meters of nearest electric pole (GPS data)	None
100 meters of nearest electric pole (household survey data)	None
Household has access to grid without additional poles	None
Average hours per day household has grid electricity[b]	None
Fraction of youth age 15 to 24 in the household with health problems in last 7 days[a]	None
Fraction of children age 5 to 14 in the household with health problems in last 7 days[a]	None
Household survey respondent currently uses family planning method	None
Household has received family planning information from television/radio/internet/telephone in last 30 days	Household has received HIV information from television/radio/internet/telephone in last 30 days
Household whose last hospital visited had grid electricity at night	None
Respondent feels safe at night by	None
All measures of safety[b]	None
At least one measure of safety[b]	None
More than half of the measures of safety[b]	None
Household had	None
A major fire in home since 2011	None
A fire caused by electric source since 2011	None
A fire caused by nonelectric source since 2011	None
Hours per day women spend at home with family	None
Hours per day men spend at home with family	None

[a] Health problems include headaches; vision and respiratory problems.

[b] The measures of perceived safety are based on four items in the follow-up household survey covering whether communal lights around households and businesses are sufficient to help walk at night, whether the respondent feels safe walking in the community at night, and whether lights in the community provide some protection against crime and wild animals.

APPENDIX D

CONVERSION FACTORS

This page has been left blank for double-sided copying.

Table D.1. Energy and pollution produced per unit of different energy sources

Survey question number	Fuel type	Energy produced	Energy produced/unit	Carbon emissions (climate change)	Carbon emissions/ unit	Black carbon produced (indoor pollution)	Black carbon (BC)/unit
K_a	Fuel wood	15.5	MJ/kg	1.52	kg CO_2/kg of fuel	0.85	g BC/kg fuel
K_b	Crop residues	15.525	MJ/kg	1.13	kg CO_2/kg of fuel	0.64	g BC/kg fuel
K_c	Straws/leaves	17.5	MJ/kg	1.17	kg CO_2/kg of fuel	1.52	g BC/kg fuel
K_d	Animal waste/dung	12	MJ/kg	1.70	kg CO_2/kg of fuel	0.12	g BC/kg fuel
K_e	Charcoal	29.4	MJ/kg	2.36	kg CO_2/kg of fuel	1.0	g BC/kg fuel
K_f	Candles	1.61	MJ/candle	0.18	kg CO_2/candle	0.066	g BC/candle
K_g	Kerosene	43	MJ/kg	3.13	kg CO_2/kg of fuel	0.9	g BC/kg
K_h	Diesel/gasoline	33.95	MJ/Liter	2.31	kg CO_2/liter of fuel	7.1	g BC/liter
K_i	LPG	24.3	MJ/Liter	1.49	kg CO_2/Liter of fuel	0.96	g BC/liter
K_j_D	Dry cell batteries, D	0.02083	kWh/battery				
K_j_AA	Dry cell batteries, AA	0.0026	kWh/battery				
K_j_AAA	Dry cell batteries, AAA	0.00141	kWh/battery				
K_j_C	Dry cell batteries, C	0.00956	kWh/battery				
K8	Car batteries	0.425	kWh/battery				
L11	Grid electricity	0.017	kWh/TZS	0.185	kg CO_2/kWh	0	g BC/kWh

Sources: Prepared by authors with the assistance of DHInfrastructure based on available information from professional and media sources as well as on product information provided by manufacturers.

Following is a list of websites of professional and media sources we used to populate this table along with some additional assumptions we made. Some of this information was obtained from online sources that are no longer available. All links listed below were functioning in February 2017, although the numbers we used were obtained much earlier, usually in 2012.

- http://physics.info/energy-chemical/. For crop residues, we averaged the energy density of the following biomass fuels: maize cobs and stalks, rice hulls and straw, coffee husks, and cotton hulls and stalks. For straws/leaves, we averaged the energy density of alfalfa, rice, and wheat.
- http://physics.info/energy-chemical/.
- http://www.fluidynenz.250x.com/enginetables.htm.
- https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf.
- http://www.earthjustice.org/sites/default/files/black-carbon/bond-et-al-2004.pdf. We took the average of the two values for wood in Table 9. We based black carbon emissions of diesel/gasoline on middle distillate oil for generators in Table 5 and adjusted from kg to liters by using an assumption of 0.84 kg/liter for gas and 0.54 for LPG.
- http://onlinelibrary.wiley.com/doi/10.1029/2003JD003697/full.
- http://greenecon.net/how-to-measure-fuel-efficiency-energy-costs-and-carbon-emissions-for-home-heating/energy_economics.html.
- http://bioscience.oxfordjournals.org/content/49/4/299.full.
- http://www.fao.org/docrep/013/i1756e/i1756e11.pdf.
- http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/1999/08/15/000009265_3961002175510/Rendered/PDF/multi_page.pdf. We converted the energy content of LPG in MJ/kG to MJ/liter, assuming a density of 0.46 KG per liter for LPG. The MJ/KG data were obtained from Table 6.
- https://en.wikipedia.org/wiki/Coal.

Table D.1. (*continued*)

- http://energy-surprises.blogspot.com/2012/05/how-green-is-my-charcoal-barbecue.html.
- We assumed an average candle in Tanzania weighs 70g and has a burn time of nine hours.
- http://enochthered.wordpress.com/2008/03/31/earth-hour-candles-and-carbon/.
- We assume a five-hour burn time for a candle and a weight of 0.025 kg.
- http://lib3.dss.go.th/fulltext/Journal/Environ%20Sci.%20Technology1998-2001/1999/no.14/14,1999%20vol.33,no14,p.2352-2362.pdf. We averaged four types of paraffin candles: 2, 4A, 4B, and 4E.
- https://www.eia.gov/environment/emissions/co2_vol_mass.cfm.
- Units were changed as needed in our analyses to match those used in our survey instrument.
- http://www.carbontrust.com/media/18223/ctl153_conversion_factors.pdf. For diesel/gas, we used the rate for petroleum.
- http://www.telegraph.co.uk/lifestyle/interiors/jeffhowell/8461279/Home-improvements-Fuel-costs.html.
- http://cngcenter.com/wp-content/uploads/2013/09/UnitsAndConversions.pdf.
- http://www.allaboutbatteries.com/Energy-tables.html.
- http://hypertextbook.com/facts/2002/RaymondTran.shtml. We were not certain about what types of car batteries are available in Tanzania and therefore averaged values found elsewhere with the most common value in this source (0.6).
- We assumed a small car battery can be expected to store around 250 watt-hours.
- http://www.chem.hawaii.edu/uham/bat.html.
- We could not find any websites claiming that grid electricity produces soot.

Table D.2. Energy-consuming devices: Energy use, pollution, and output estimates

Survey question number	Energy-consuming devices	Energy use	Energy use unit	Energy produced	Energy produced/ unit	Carbon emissions (climate change)	Carbon emissions unit	Black carbon produced (internal pollution)	Black carbon (BC)/unit	Output	Output unit
D1	Fluorescent light bulb	0.015	kWh			8	g CO_2/hr			900	Lumens
D2	Incandescent light bulb	0.060	kWh			33	g CO_2/hr			890	Lumens
D3	Energy-saving bulb	0.01	kWh			6	g CO_2/hr			725	Lumens
D4	Flashlight	0.0009	kWh			0.50	g CO_2/hr			281	Lumens
D5	Candle hours	NA				24	g CO_2/ candle/hr	0.014	g BC/ candle hr	13	Lumens
D6	Kerosene lantern	8.2	g/hr			25.67	g CO_2/hr	0.007	g BC/hr	68	Lumens
D7	Pressurized kerosene lantern	85	g/hr			266.1	g CO_2/hr	0.077	g BC/hr	1,300	Lumens
D8	Traditional or charcoal stove	450	g/hr			9261	g CO_2/hr	0.45	g BC/hr		
D9	Kerosene stove	114.8	g/hr			35	g CO_2/hr	0.10	g BC/hr		
D10	Electric stove	3	kWh			1660	g CO_2/hr				
D11	Gas cooker	45	g/hr			139.05	g CO_2/hr	0.0234	g BC/hr		
D12	Car or motorcycle battery (for household use)			0.5010	kWh						
D13	Generator set	0.7	Liters/hr	2.0000	kWh						
D14	Solar PV system			0.0408	kWh						
D15	Pico-hydro system			0.45	kWh						
D16	Television	0.12	kWh			66	g CO_2/hr				
D17	Air conditioner	1	kWh			553	g CO_2/hr				
D18	Electric fan	0.1	kWh			55	g CO_2/hr				
D19	VCD/DVD player	0.02	kWh			11	g CO_2/hr				
D20	Radio/CD player	0.035	kWh			19	g CO_2/hr				
D21	Electric water pump	0.125	kWh			69	g CO_2/hr			1,620	L/hr

Table D.2. (*continued*)

Survey question number	Energy-consuming devices	Energy use	Energy use unit	Energy produced	Energy produced/ unit	Carbon emissions (climate change)	Carbon emissions unit	Black carbon produced (internal pollution)	Black carbon (BC)/unit	Output	Output unit
D22	Diesel water pump	1,397.5	g/hr			4,174.13	g CO_2/hr	10.02	g BC/hr	60,000	L/hr
D23	Manual water pump	0	g/hr			0	g CO_2/hr	0	g BC/hr	1,200	L/hr
D24	Electric motor	100	kWh			55,338	g CO_2/hr				
D25	Diesel/gasoline motor	2,176.2	g/hr			6,500	g CO_2/hr	15.60	g BC/hr		
D26	Electric tools	1.015	kWh			60.88	g CO_2/hr				
D27	Sewing machine	0.1	kWh			55	g CO_2/hr				
D28	Sound equipment	0.0225	kWh			11	g CO_2/hr				
D29	Iron	0.98	kWh			542	g CO_2/hr				
D30	Washing machine	3	kWh			1,660	g CO_2/hr				
D31	Vacuum cleaner	1	kWh			553	g CO_2/hr				
D32	Microwave oven	1.23	kWh			681	g CO_2/hr				
D33	Water heater	2	kWh			1107	g CO_2/hr				
D34	Computer	0.13	kWh			72	g CO_2/hr				
D40	Satellite dish	0.05	kWh			27.67	g CO_2/hr				
D41	Refrigerator/ freezer	0.16	kWh			88.54	g CO_2/hr				
G1	Landline telephone	0.002	kWh			1.11	g CO_2/hr				
G7	Cell phone (charger)	0.009	kWh			4.98	g CO_2/hr				

Sources: Prepared by authors with assistance of DHInfrastructure based on available information from professional and media sources as well as on product information provided by manufacturers.

Following is a list of websites of professional and media sources we used to populate this table along with some additional assumptions we made. Some of this information was obtained from online sources that are no longer available. All links listed below were functioning in February 2017, although the numbers we used were obtained much earlier, usually in 2012.

Please see Table D.3 for all the electric water pumps that were identified to calculate the output.

- The following formula was used to calculate carbon emission rates for D1, D2, D3, D4, D10, D16, D17, D18, D19, D20, D21, D24, D26, D27, D28, D29, D30, D31, D32, D33, D34, D40, D41, G1, and G7: Energy Use*Emissions from the National Grid (from Responsible Tourism Tanzania; available at http://www.rttz.org/who-we-are/ghg/. The website states ". . . emissions [by electricity generation] from the national grid are 0.060 KG/CO2 per kWh."
- http://home.howstuffworks.com/question236.htm.
- http://www.lowes.com/projects/decorate-and-entertain/Lightbulb-Buying-Guide/project.
- http://www.bulbs.com/learning/pickacfl.aspx.
- 70W is the average wattage of three typical wattage levels for incandescent bulbs (40, 60, 100). However, we used 60W, as a 70W bulb is uncommon.

Table D.2. (*continued*)

- http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=2.1.16.
- http://www.amazon.com/12V-75mA-Incandescent-Flashlight-Bulb/dp/B007Z7QB9A. The calculation for the flashlight energy use is Watts = Volts x Amps; 12 volts x 9 milliamps = 0.0009 kilowatts.
- http://m.dhgate.com/product/brand-new-0-9w-rechargeable-flashlight-abs/218085112.html.
- http://www.dewalt.com/tools/cordless-flashlight-bulbs-dw9043.aspx.
- We use the fuel source data on candles to estimate energy use from candles.
- http://enochthered.wordpress.com/2008/03/31/earth-hour-candles-and-carbon/.
- https://answers.yahoo.com/question/index?qid=20061027092336AAKNYGD.
- Based on a paraffin wax candle that burns according to the equation: $C_{25}H_{52}$ + $38O_2$ --> $25CO_2$ + $26H_2O$ Mol.wt. of $C_{25}H_{52}$ = (25x12)+(52x1) = 352 Mol.wt. of CO_2 = (1x12)+(2x16) = 44 So 352g of wax yields (25x44) = 1100g of CO_2. A household candle of 70g (avg. weight of candle in Tanzania) will burn for about nine hours; therefore, one hour will burn 7.8g of candle and produce 7.8/352 x 1100 = 24g of CO_2 per hour. http://www.michaelsmithnews.com/2014/03/the-chemistry-of-earth-hour-1-candle-x-1-hour-8-x-the-co2-from-1-lightbulb-x-1-hour.html.
- http://lib3.dss.go.th/fulltext/Journal/Environ%20Sci.%20Technology1998-2001/1999/no.14/14,1999%20vol.33,no14,p.2352-2362.pdf. Our estimate is based on the average elemental carbon emissions rate of the paraffin candle types from Table 1 in this appendix (0.94 g BC/kg paraffin). We assume a weight of 0.025 kg per candle.
- http://evanmills.lbl.gov/pubs/pdf/offgrid-lighting.pdf. We assumed that the kerosene lantern consumes 0.010 liters of kerosene per hour based on the LBL study. Thus, we calculate g/hr as follows: 820 g/L * 0.010 l/hr = 8.2 g/hr fuel consumption.
- http://www.engineeringtoolbox.com/liquids-densities-d_743.html. The density of kerosene is 820 g/L.
- https://webcache.googleusercontent.com/search?q=cache:vjqfhkyDqPIJ:https://www.scipress.com/ILCPA.54.1.pdf+&cd=7&hl=en&ct=clnk&gl=us
- http://www.energia-africa.org/fileadmin/files/media/reports/Nigeria/Seedfunding%20case%20study%20Penetrating%20LPG%20Use%20in%20Lagos%20State.pdf. This value was obtained by using the following formula: CO_2 emissions from charcoal stove (g of CO_2/MJ) and charcoal energy content (MJ/kg of charcoal) and stove energy use (kg charcoal/hour).
- http://www.fao.org/docrep/013/i1756e/i1756e11.pdf. This source says the estimated rate of black carbon emissions from charcoal-making is 0.2g/kg. This was multiplied by the corresponding energy use rate.
- http://www.commercialfuelsolutions.co.uk/pages.php?pageid=2. The specific gravity of diesel fuel is 0.82/kg.
- http://www.alibaba.com/product-gs/377568170/641_Kerosene_Stove.html. This product consumes 0.14 liters of kerosene per hour. To convert to g/hr, we multiplied the rate and the specific gravity of diesel fuel together.
- http://www.kerosenestoves.net/.
- http://answers.yahoo.com/question/index?qid=20100307191621AAeC7iS.
- http://www.chem.hawaii.edu/uham/bat.html.
- This is calculated by using the same methodology used to calculate fuel consumption of a diesel motor (D25).
- http://siteresources.worldbank.org/EXTENERGY/Resources/336805-1157034157861/ElectrificationAssessmentRptAnnexesFINAL17May07.pdf. This is based on a 2 kW diesel generator, which is the smallest diesel generator set specified in the World Bank document. We did not find a basis for assuming a generator size used for home power production and therefore used the smallest.
- http://answers.yahoo.com/question/index?qid=20070619001836AAjvU6D.
- http://www.fnu.zmaw.de/fileadmin/fnu-files/publication/working-papers/Ondraczek_2011_Working-Paper-FNU_195.pdf. We estimate this by using the formula, (50*0.17*8760)/((8760/24)*5)/1000. This is an estimate of the average over five hours, assuming a 50W panel. However, solar PV systems produce varying amounts of energy throughout the day, so a standard per hour metric is not possible. We assume a 50W solar system (based on system sizes in the cited source) with a capacity factor of 17 percent. This is a typical capacity factor for this location and assumes that the system produces electricity for five hours during the day. The formula here calculates the hourly electricity generated by the system during the hours when it is generating. It multiplies the average hourly generation over the entire year by 24 to get the average daily generation. It then divides that amount by the number of hours that the system is generating (5).
- http://news.energysage.com/what-is-the-power-output-of-a-solar-panel/.
- https://answers.yahoo.com/question/index?qid=20080409072650AAQY5O6.
- http://www.fnu.zmaw.de/fileadmin/fnu-files/publication/working-papers/Ondraczek_2011_Working-Paper-FNU_195.pdf. For the pico-hydro system, the capacity factor is 45 percent. However, the actual energy production of a small hydropower system can vary substantially; it can range from a 1 kW system up to several MW in size. It is important to understand that this is highly site-specific and will vary from respondent to respondent. To be conservative, we have chosen 1kW here as the low end of the range.
- http://iosrjournals.org/iosr-jestft/papers/vol9-issue1/Version-3/J09135967.pdf.
- http://www.myprius.co.za/D04%2010%20-%20%20Bredekamp%20A.pdf. We averaged several types of TVs, DVD players, and mini hi-fis that are common in South Africa. For sound equipment, we took numbers for different types of mini hi-fis.
- http://www.kestrelwind.co.za/content.asp?PageID=309.
- http://www.absak.com/library/power-consumption-table. We averaged two types of A/C units: room and central. We also took the average of two types of electric fans: ceiling and table.

Table D.2. (*continued*)

- The kWh range in South Africa is: 0.5/1/1.44.
- Assume typical floor/desk fan in South Africa.
- DVD player generic kWh range in South Africa: 0.02 to 0.025.
- The kWh range for radios in South Africa is: 0.12/.07/.40.
- http://www.amazon.com/DuroMax-XP904WP-4-Cycle-Powered-Portable/dp/B000MX9RQ8/ref=sr_1_1?s=hi&ie=UTF8&qid=1343954059&sr=1-1&keywords=Diesel+water+pump.
- http://icmsa.co.za/Water%20pump-South%20Africa.htm. The average of three types of water pumps (700 l/min and 1,600 l/min are from this source; 427 gal/min is from #31) was 1,305, but we decided to use a number a little below the average based on the idea that the available water pumps may be relatively less powerful.
- http://sunshineworks.com/stainless-steel-deep-well-hand-pump.htm.
- http://www.simplepump.com/OUR-PUMPS/Hand-Operated.html.
- http://solution4africa.com/product-hand-pump.html.
- We averaged different types of electric waterpumps from as source that that is no longer available.
- https://www.villagevolunteers.org/wp-content/uploads/2011/06/Hand-Powered-Water-Pumps.pdf.
- http://essay.utwente.nl/58510/1/scriptie_G_Maleko.pdf. Electric/diesel motors are used to run grain mills in Tanzania and serve the whole community rather than just single households.
- http://iopscience.iop.org/1748-9326/6/3/034002/pdf/1748-9326_6_3_034002.pdf. 7.5 kWh diesel motor consumes 2.6 liters of diesel per hour. We took the average of the high and ow fuel consumption per kWh estimates (pg. 4) and multiplied them by the kW output of the diesel generator. Then we converted to gram from liter.
- http://www.repp.org/repp_pubs/pdf/devGGas.pdf. This source states that a typical kerosene CO2 emission factor ranges from 2.4 to 2.5 kg/liter. We converted liter to g and then multiplied it by diesel/gasoline motor's electricity use.
- http://www.made-in-china.com/. After finding jig saws (520, 350, 710, and 710), electric chain saws (1600, 1300, 1300, and 1300), rotary hammers (800, 850, 1050, 1120, 500, 500, 800, 850, and 850), and circular saws (1350, 1200, 1050, 1500, 1200, 1500, 1400, and 1300) that look similar to the ones in #40, we averaged across all of their energy use rates.
- http://www.absak.com/library/power-consumption-table.
- http://answers.yahoo.com/question/index?qid=20070629122044AABaAAr.
- Sound equipment refers to mini hi-fis. Small appliances such as VCRs and portable stereos consume less energy than sewing machines: http://www.absak.com/library/power-consumption-table.
- http://www.kestrelwind.co.za/content.asp?PageID=309.
- We averaged 4,500 W and 5,500 W from a source that is no longer available.
- http://www.chabotspace.org/assets/BillsClimateLab/Electrical%20Appliance%20Typical%20Energy%20Consumption%20Table.pdf.
- http://answers.yahoo.com/question/index?qid=20090422100301AAxuHXB.
- https://answers.yahoo.com/question/index?qid=20100730123650AAox0Y6.

Table D.3. Conversion factors for water pumps

#	Units	Liters/minute	Type	Source	Depth
40	Liters/minute	40	Electric	Source no longer available.	Well
558	Gal/hour	35	Electric	Source no longer available.	5 feet
10	Gal/minute	38	Electric	Source no longer available.	25 feet
300	Gal/hour	19	Electric	http://www.simplepump.com/OUR-PUMPS/Motorized.html	Well
7.5	Gal/minute	28	Electric	http://www.grainger.com/Grainger/DAYTON-Shallow-Well-Jet-Pump-System-4HEZ9?cm_mmc=CSE:Shopping-_-Pumps-_-Well%20Pumps-_-4HEZ9&srccode=cii_13736960&cpncode=32-145833708-2	5 feet
6.1	Gal/minute	23	Electric	http://www.grainger.com/Grainger/DAYTON-Shallow-Well-Jet-Pump-System-4HEZ9?cm_mmc=CSE:Shopping-_-Pumps-_-Well%20Pumps-_-4HEZ9&srccode=cii_13736960&cpncode=32-145833708-2	10 feet
5	Gal/minute	19	Electric	http://www.grainger.com/Grainger/DAYTON-Shallow-Well-Jet-Pump-System-4HEZ9?cm_mmc=CSE:Shopping-_-Pumps-_-Well%20Pumps-_-4HEZ9&srccode=cii_13736960&cpncode=32-145833708-2	15 feet
4	Gal/minute	15	Electric	http://www.grainger.com/Grainger/DAYTON-Shallow-Well-Jet-Pump-System-4HEZ9?cm_mmc=CSE:Shopping-_-Pumps-_-Well%20Pumps-_-4HEZ9&srccode=cii_13736960&cpncode=32-145833708-2	20 feet
3.4	Gal/minutes	13	Electric-solar	http://www.solar-electric.com/sds-q-128.html	100 feet
5	Gal/minute	19	Hand	http://www.simplepump.com/OUR-PUMPS/Hand-Operated.html	Well
5	Gal/minute	19	Hand	http://sunshineworks.com/stainless-steel-deep-well-hand-pump.htm	Well
5	Gal/minute	19	Hand	http://solution4africa.com/product-hand-pump.html	Well
22	Liters/minute	22	Hand	Source no longer available.	7 meters
10	Liters/minute	10	Hand	Source no longer available.	45 meters
427	Gal/minute	1,616	Diesel	http://www.amazon.com/DuroMax-XP904WP-4-Cycle-Powered-Portable/dp/B000MX9RQ8/ref=sr_1_1?s=hi&ie=UTF8&qid=1343954059&sr=1-1&keywords=Diesel+water+pump	26 feet
700	Liters/minute	700	Diesel	http://icmsa.co.za/Water%20pump-South%20Africa.htm	
1,600	Liters/minute	1,600	Diesel	http://icmsa.co.za/Water%20pump-South%20Africa.htm	

Source: Prepared by authors with assistance of DHInfrastructure based on available information from professional and media sources as well as on product information provided by manufacturers.

This page has been left blank for double-sided copying.

APPENDIX E

SUPPLEMENTARY TABLES ON ESTIMATED IMPACTS

This page has been left blank for double-sided copying.

In this appendix, we present tables with additional information about the estimated impacts reported in Chapters V, VI, and VII. In addition to the columns in the tables with impact estimates shown in those chapters (namely, comparison/control group mean, estimated impact, and *p*-value from the test of statistical significance of the estimated impact), we show intervention/treatment group mean and sample sizes for each outcome. Following is the list of tables in this appendix:

Table E.1. Community-level T&D lines impacts

Community outcome at follow-up	Intervention mean	Comparison mean	Impact	*p*-value	Sample size
Connection rate domain					
Primary outcome					
Fraction of households connected to national grid (based on community survey data)	0.20	0.14	0.06***	0.01	356
Secondary outcomes					
Fraction of households connected to national grid (based on household listing)[a]	0.26	0.10	0.15***	0.00	358
Fraction of households within 30 meters of grid [a]	0.42	0.13	0.29***	0.00	358
Community has access to national grid	0.97	0.53	0.45***	0.00	358
Community has access to isolated grid	0.07	0.03	0.04	0.20	358
Community has access to generator	0.52	0.64	-0.12	0.18	358
Community has access to solar, windmill, and other electricity sources	0.96	0.98	-0.02	0.53	358
Energy use domain					
Secondary outcomes					
TANESCO informed households fully about low tariff requirements	0.31	0.20	0.11**	0.03	358
TANESCO informed households partially about low tariff requirements	0.51	0.23	0.28***	0.00	358
Community has access to kerosene	0.93	0.94	-0.01	0.77	358
Community has access to diesel/gasoline	0.84	0.83	0.00	0.86	358
Community has access to firewood, charcoal, or dung	0.98	0.92	0.07**	0.04	358
Education and child time use domain					
Primary outcome					
Communities has electrified school(s)	0.53	0.35	0.18***	0.01	358
Secondary outcomes					
Distance from community to nearest preprimary school (km)	3.28	3.32	-0.04	0.71	358
Distance from community to nearest primary school (km)	1.61	1.61	-0.01	0.89	358
Distance from community to nearest secondary school (km)	2.45	3.12	-0.67	0.48	358
Health and safety domain					
Primary outcome					
Community has electrified health facility (dispensary, health center, diagnostic laboratory, hospital)	0.37	0.29	0.08	0.22	358
Secondary outcomes					
Community has a health facility open at night	0.25	0.26	-0.01	0.91	358
Distance from community to nearest health facility (km)	1.48	1.98	-0.50	0.18	358
Distance from community to obtain vaccination service (km)	1.44	3.08	-1.64	0.15	358
Distance from community to obtain X-ray service (km)	25.92	33.81	-7.89*	0.08	358
Distance from community to obtain malaria test (km)	3.29	4.51	-1.23*	0.08	358
Distance from community to obtain HIV test (km)	3.10	3.93	-0.83*	0.07	358
Community has light available on a cloudy night	0.85	0.63	0.22***	0.00	358
Perception of women's safety at night[b]				0.76	358
Feels very safe	0.10	0.12	-0.01		
Feels somewhat safe	0.63	0.57	0.06		

Table E.1. (*continued*)

Community outcome at follow-up	Intervention mean	Comparison mean	Impact	*p*-value	Sample size
Feels very unsafe	0.27	0.31	-0.04		
Perception of men's safety at night[b]			0.0*	0.08	358
Feels very safe	0.20	0.18	0.02		
Feels somewhat safe	0.73	0.71	0.03		
Feels very unsafe	0.06	0.11	-0.05		
Most community members have piped water	0.34	0.36	-0.02	0.67	358
Community has a police post	0.23	0.18	0.05	0.33	358
Business and adult time use domain					
Primary outcome					
Community has at least one electrified business	0.97	0.52	0.44***	0.00	358
Secondary outcomes					
Community has an electrified repair shop	0.49	0.30	0.19***	0.00	358
Community has an electrified tea/coffee shop, guest house, or hotel	0.77	0.47	0.30***	0.00	358
Community has other electrified businesses	0.96	0.52	0.36***	0.00	358
Fraction of all businesses in community electrified	0.49	0.33	0.16***	0.00	355
Fraction of weekly markets in community electrified	0.03	0.01	0.03**	0.02	358
Fraction of all agricultural repair shops in community electrified	0.12	0.09	0.03	0.51	358
Fraction of all vehicle repair shop in community electrified	0.27	0.25	0.02	0.63	358
Fraction of all restaurants, tea/coffee shops in community electrified	0.33	0.22	0.10**	0.02	358
Fraction of all telephone repair shop in community electrified	0.71	0.39	0.32***	0.00	358
Fraction of all carpentry shops in community electrified	0.20	0.17	0.03	0.45	358
Fraction of all hotels/guesthouses in community electrified	0.50	0.34	0.17***	0.00	358
Fraction of all hair salons/barber shops in community electrified	0.79	0.41	0.38***	0.00	358
Fraction of all tailor shops in community electrified	0.17	0.17	-0.01	0.87	358
Fraction of all newspaper shops in community electrified	0.02	0.04	-0.02	0.47	358
Fraction of all cafes in community electrified	0.15	0.13	0.02	0.75	358
Fraction of all grain mills in community electrified	0.62	0.40	0.22***	0.01	358
Fraction of all saw mills in community electrified	0.32	0.25	0.07	0.23	358
Fraction of all oil mills in community electrified	0.21	0.08	0.13*	0.08	358
Fraction of all mobile money banking in community electrified	0.51	0.35	0.16**	0.03	358
Fraction of all welding and metal fabrication in community electrified	0.60	0.35	0.24**	0.02	358
Fraction of all car battery charging shops in community electrified	0.34	0.31	0.03	0.72	358
Community has an electrified post office	0.06	0.05	0.01	0.73	358
Community has farming, fishing, livestock, or hunting as the main source of income	0.73	0.76	-0.03	0.28	358
Economic well-being domain					
Primary outcome					
Natural log of price per acre of residential land in community	14.50	14.16	0.34**	0.03	354
Secondary outcomes					
Natural log of price per acre of farmland in community	13.40	13.21	0.19	0.22	308
Community is one in which most people have mobile phones	0.26	0.20	0.06	0.21	358

Table E.1. (*continued*)

Community outcome at follow-up	Intervention mean	Comparison mean	Impact	*p*-value	Sample size
Community is one with a new school at follow-up	0.52	0.50	0.03	0.73	358
Community is one with new water supply at follow-up	0.31	0.41	-0.09**	0.03	358
Community is one with new health center at follow-up	0.27	0.19	0.08***	0.01	358
Community is one with new roads at follow-up	0.50	0.45	0.06	0.33	358
Community with plans for a new/upgraded school within the next two years	0.43	0.50	0.07	0.45	358
Community with plans for a new/upgraded public water supply in the next two years	0.46	0.49	-0.03	0.60	358
Community with plans for a new/upgrade health center in the next two years	0.50	0.40	0.09	0.22	358
Community with plans for new/upgraded roads in the next two years	0.43	0.47	-0.04	0.71	358
Community with plans for new/upgraded market in the next two years	0.39	0.29	0.10	0.13	358
Composition and mobility domain					
Number of total households in community (based on household listing)	210.90	202.47	8.42	0.64	357
Secondary outcomes					
Fraction of households in community at follow-up who are in-migrants since 2011	0.02	0.02	0.00	0.35	357
Fraction of households in community at follow-up who are newly formed since 2011	0.01	0.02	0.00*	0.09	357
Community identified as *mtaa* (urban)	0.27	0.39	-0.11***	0.01	358
Community boundaries changed since 2011	0.34	0.35	-0.02	0.72	358

Source: Tanzania energy sector baseline and follow-up community surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for community-level explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes a total of 358 communities with 178 in the intervention group and 180 in the comparison group. Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. We calculated statistics using community size (number of households) as weights to make the community-level results apply to the households in those communities.

[a] This outcome captures only the set of sub-villages covered by the household survey and only households that were in the community and not connected or within 30 meters of a pole at baseline. The remaining variables in this table cover all households in all sub-villages covered by the community survey.

[b] The statistical significance of the results for women's and men's perceived safety at night is calculated across the three levels of these outcomes (very safe, somewhat safe, very unsafe).

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

Table E.2a. Household-level T&D lines impacts: Full analysis sample

Household outcome at follow-up	Intervention mean	Comparison mean	Impact	*p*-value	Sample size
Connection rate domain					**8,896**
Primary outcome					
Household is connected to national grid	0.21	0.11	0.10***	0.00	8,896
Secondary outcomes					
Household is connected to MCC lines	0.10	0.01	0.09***	0.00	8,870
Household is connected to non-MCC lines built after 2011	0.07	0.06	0.02	0.14	8,870
Household is connected to non-MCC lines built before 2011	0.03	0.04	-0.01	0.45	8,870
Household is with access to grid without additional poles	0.51	0.32	0.19***	0.00	8,896
Household is within 30 meters of nearest electric pole (GPS data)	0.33	0.14	0.19***	0.00	8,721
Household is within 30 meters of nearest electric pole (household listing data)	0.47	0.22	0.25***	0.00	8,371
Household is within 30 meters of nearest electric pole (household survey data)	0.44	0.24	0.20***	0.00	8,896
Household is within 40 meters of nearest electric pole (GPS data)	0.42	0.20	0.22***	0.00	8,721
Household is within 40 meters of nearest electric pole (household survey data)	0.52	0.28	0.23***	0.00	8,896
Household is within 50 meters of nearest electric pole (GPS data)	0.49	0.24	0.25***	0.00	8,721
Household is within 50 meters of nearest electric pole (household survey data)	0.57	0.32	0.25***	0.00	8,896
Household is within 100 meters of nearest electric pole (GPS data)	0.61	0.32	0.29***	0.00	8,721
Household is within 100 meters of nearest electric pole (household survey data)	0.71	0.44	0.27***	0.00	8,849
Average years household has been connected to national grid[a]	0.48	0.23	0.25***	0.00	8,816
Average hours per day household has grid electricity[a]	3.30	1.63	1.67***	0.00	8,896
Energy use domain					
Primary outcome					
Monthly mount of electricity used by household from any source (kWh)	20.70	18.11	2.59	0.13	8,896
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	7.31	5.24	2.07	0.38	8,896
Secondary outcomes					
Household uses electricity from any source except batteries	0.29	0.27	0.02	0.20	8,896
Household owns a generator powered by liquid fuel/solar/hydro/wind	0.22	0.31	-0.09***	0.00	8,896
Monthly amount of grid electricity used by household (kWh)	16.99	9.00	8.00***	0.00	8,837
Monthly amount of nongrid electricity used by household (kWh)	3.88	9.16	-5.28***	0.00	8,896
Monthly amount of kerosene used by household (liter)	1.39	1.70	-0.32	0.34	8,896
Monthly amount of solid fuel used by household (kg)	148.79	159.34	-10.54	0.52	8,896
Number of electric tools/appliances owned by household	4.11	3.61	0.51***	0.00	8,896
Household owns a television	0.22	0.19	0.03**	0.03	8,896
Monthly hours of electric tools/appliances used by household	604.63	489.37	115.26***	0.00	8,896
Monthly hours of electric fan used by household	3.39	1.83	1.57**	0.04	8,896
Monthly amount of light consumed by household (lumen-hours)	312,871	236,050	76,821***	0.00	8,896
Total monthly cost of light consumed by household (TZS)	832	15,437	-14,605	0.25	8,859
Household owns at least one mobile phone	0.85	0.85	0.00	0.71	8,896
Monthly household costs for mobile phone recharge (TZS)	1,961	2,518	-558***	0.00	8,874

Table E.2a. (*continued*)

Household outcome at follow-up	Intervention mean	Comparison mean	Impact	*p*-value	Sample size
Education and child time use domain					
Primary outcome					
Average hours per day children (age 5 to 14) spend studying at night[b]	0.37	0.40	-0.02	0.44	5,906
Secondary outcomes					
Average hours children (age 5 to 14) spend in total studying	0.66	0.68	-0.02	0.56	5,906
Average hours youth (age 15 to 24) spend studying at night	1.35	1.27	0.09	0.31	1,826
Average hours youth (age 15 to 24) spend in total studying	1.80	1.73	0.07	0.47	1,826
Hours children spent collecting water and fuel in last 24 hours	0.85	0.83	0.01	0.83	5,673
Hours children spent performing other household chores in last 24 hours	0.62	0.64	-0.02	0.55	5,673
Hours children spent on leisure/entertainment in last 24 hours	2.28	2.22	0.06	0.58	5,673
Hours children spent watching television in last 24 hours[c]	0.39	0.27	0.12***	0.00	5,673
Hours children spent sleeping at night in last 24 hours	9.22	9.14	0.08*	0.07	5,673
Fraction of children in household age 5 to 14 attending school	0.78	0.79	-0.01	0.31	6,736
Household has a child age 5 to 14 attending a school with electricity	0.24	0.18	0.06**	0.01	6,736
Health and safety domain					
Primary outcome					
Fraction of youth age 15 to 24 in the household with health problems in last 7 days[d]	0.25	0.26	-0.02	0.37	5,146
Fraction of children age 5 to 14 in the household with health problems in last 7 days[d]	0.30	0.29	0.00	0.78	6,736
Secondary outcomes					
Fraction of households in which a member ages 15 to 24 missed work in the last 30 days due to illness	0.17	0.19	-0.02	0.35	4,905
Monthly amount of internal pollution from soot (grams of black carbon)	173.93	156.06	17.87	0.34	8,896
Monthly amount of external pollution from carbon (kg CO2)	276.85	289.43	-12.58	0.67	8,896
Household received family planning information from television/radio/internet/phone in last 30 days	0.46	0.44	0.02	0.43	8,896
Household survey respondent currently uses family planning method	0.34	0.33	0.01	0.49	7,529
Household received HIV info from TV/radio/internet/phone in last 30 days	0.44	0.43	0.01	0.59	8,896
Household has ever visited an electrified hospital at night	0.35	0.33	0.03	0.23	8,896
Respondent feels safe at night by all measures of safety[e]	0.12	0.06	0.06***	0.00	8,896
Respondent feels safe at night by at least one measure of safety[e]	0.81	0.66	0.15***	0.00	8,896
Respondent feels safe at night by more than half of the measures of safety[e]	0.49	0.29	0.20***	0.00	8,896
Household has had a major fire in home since 2011	0.04	0.04	0.00	0.92	8,896
Household has had a fire caused by electric source since 2011	0.00	0.00	0.00	0.66	8,896
Household has had a fire caused by nonelectric source since 2011	0.04	0.04	0.00	0.89	8,896

Table E.2a. (*continued*)

Household outcome at follow-up	Intervention mean	Comparison mean	Impact	*p*-value	Sample size
Business and adult time use domain					
Primary outcome					
Household operates any income generating activities (IGA)	0.63	0.63	0.01	0.70	8,896
Secondary outcomes					
Household operates any IGA that uses grid electricity	0.09	0.07	0.02***	0.01	8,896
Household's monthly revenue from IGA (TZS)	155,829	157,028	-1,199	0.95	7,613
Household's annual revenue from IGA (TZS)	1,606,617	1,432,262	174,355	0.43	7,718
Household has at least one member who is a paid employee	0.18	0.18	0.00	0.94	8,896
Women's time use: hours per day on each type of activity					
Wage labor (agricultural and nonagricultural)	0.71	0.64	0.07	0.34	8,044
Nonwage labor/other productive activities (farming and other activities)	1.06	0.91	0.15**	0.04	8,044
Other IGA	1.25	1.19	0.06	0.45	8,044
Household chores and child care	2.43	2.45	-0.02	0.80	8,044
Collecting fuel and water	1.43	1.30	0.14**	0.05	8,044
Cooking, processing, and preparing food	3.38	3.27	0.11*	0.10	8,044
Reading and studying	0.03	0.03	0.00	0.62	8,044
Socializing and resting	4.66	4.63	0.02	0.81	8,044
Spending time at home with family[c]	2.29	2.07	0.22**	0.01	8,044
Watching television[c]	0.33	0.26	0.07**	0.01	8,044
Sleeping at night	8.64	8.62	0.02	0.54	8,044
Men's time use: hours per day on each type of activity					
Wage labor (agricultural and nonagricultural)	1.61	1.53	0.07	0.62	6,208
Nonwage labor/other productive activities (farming and other activities)	1.42	1.35	0.07	0.48	6,208
Other IGA	1.66	1.80	-0.14	0.28	6,208
Household chores and child care	0.45	0.46	0.00	0.93	6,208
Collecting fuel and water	0.57	0.45	0.11**	0.01	6,208
Cooking, processing, and preparing food	0.26	0.28	-0.02	0.51	6,208
Reading and studying	0.10	0.07	0.03*	0.05	6,208
Socializing and resting	5.86	5.81	0.06	0.64	6,208
Spending time at home with family[c]	2.09	1.97	0.13*	0.08	6,208
Watching television[c]	0.45	0.36	0.09**	0.02	6,208
Sleeping at night	8.46	8.41	0.04	0.35	6,208
Economic well-being domain					
Primary outcome					
Annual household nonelectricity consumption (TZS)	3,296,061	3,401,477	-105,416	0.41	8,008
Secondary outcomes					
Annual household income (TZS)	2,659,346	2,847,584	-188,237	0.44	7,350
Household per capita daily consumption (TZS)	1,886.38	1,940.83	-54.45	0.48	8,008
Household per capita daily income (TZS)	1,486.68	1,633.06	-146.37	0.37	7,350
Household consumes less than $1 per day per person	0.74	0.76	-0.02	0.33	8,008

Table E.2a. (*continued*)

Household outcome at follow-up	Intervention mean	Comparison mean	Impact	*p*-value	Sample size
Household consumes less than $2 per day per person	0.93	0.93	0.00	0.54	8,008
Total household assets (TZS)	52,839,660	59,511,028	-6,671,368	0.83	7,019
Household lives in an electrifiable dwelling based on wall and roof materials	0.74	0.75	-0.02	0.46	8,896
Average number of rooms in household for sleeping	3.69	3.72	-0.03	0.61	8,896
Household has a flush toilet	0.21	0.22	-0.01	0.59	8,896
Household has piped water in rainy and dry seasons	0.07	0.06	0.00	0.67	8,896
Composition and mobility					
Secondary outcomes					
Household moved within community since 2011	0.09	0.08	0.01	0.26	8,269
Household migrated out since 2011	0.02	0.03	0.00	0.49	8,896
Household out-migrated since 2011 and was among those with baseline income above district median	0.03	0.03	0.01	0.42	4,504
Household out-migrated since 2011 and was among those with baseline income below district median	0.02	0.03	-0.01	0.14	4,017

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for lagged (baseline) outcome when available. The analysis sample includes a total of 8,897 households with 4,467 in the intervention group and 4,430 in the comparison group. Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] The average includes households that were not connected to the national grid.

[b] Parents were asked how many hours per day each child spends studying during the day and at night, and these numbers were averaged across all children of that age in the household. For other activities, parents were simply asked how much time one specific child age 5-14 spent on that activity during the past 24 hours.

[c] Time children spent watching television is a component of the measure of time they spent on leisure/entertainment; for adults (women and men), time spent at home with family and watching television are components of the measure of time spent on socializing and resting.

[d] Health problems include headaches; vision and respiratory problems.

[e] The measures of perceived safety are based on four items in the follow-up household survey covering whether communal lights around households and businesses are sufficient to help walk at night, whether the respondent feels safe walking in the community at night, and whether lights in the community provide some protection against crime and wild animals.

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

Table E.2b. Household-level T&D lines impacts: Subgroup results by gender of household head

	Female-headed households			Male-headed households					Sample size	
	Comparison mean	Impact	*p*-value	Comparison mean	Impact	*p*-value	Difference in impacts	*p*-value of difference in impacts	Intervention	Comparison
Household is connected to national grid	0.09	0.08	0.00	0.11	0.11	0.00	-0.03	0.09*	3,954	4,430
Monthly amount of electricity used by household from any source (kWh)	11.98	2.42	0.28	19.82	2.51	0.18	-0.10	0.97	3,954	4,430
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	2.98	-1.18	0.35	5.73	2.51	0.38	-3.69	0.10	3,954	4,430
Average hours per day children (age 5 to 14) spend studying at night	0.40	-0.05	0.26	0.40	-0.01	0.72	-0.04	0.39	2,633	3,007
Fraction of youth age 15 to 24 with health problems in last 7 days[a]	0.29	-0.01	0.72	0.25	-0.02	0.37	0.01	0.83	2,266	2,632
Fraction of children age 5 to 14 with health problems in last 7 days[a]	0.30	0.01	0.71	0.29	0.01	0.75	0.00	0.88	3,025	3,402
Household operates any IGA	0.54	0.01	0.56	0.65	0.00	0.86	0.01	0.66	3,954	4,430
Annual household nonelectricity consumption (TZS)	2,622,439	-188,927	0.21	3,672,844	-101,170	0.49	-87,757	0.61	3,569	3,972

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for lagged (baseline) outcome when available. The analysis sample includes a total of 1,972 female headed households (1,025 comparison and 947 intervention) and 6,412 male headed households (3,405 comparison and 3,007 intervention). Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. Sample size for outcomes related to children reflect households with children. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Health problems include headaches; vision and respiratory problems.

/**/** The difference in the estimated impacts for the subgroups is significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Table E.2c. Household-level T&D lines impacts: Subgroup results by age of household head

	Households with head under age 25			Households with head over age 25					Sample size	
	Comparison mean	Impact	*p*-value	Comparison mean	Impact	*p*-value	Difference in impacts	*p*-value of difference in impacts	Intervention	Comparison
Household is connected to national grid	0.15	-0.02	0.69	0.11	0.10	0.00	-0.12	0.02**	3,948	4,425
Monthly amount of electricity used by household from any source (kWh)	18.17	-6.81	0.22	18.01	2.73	0.12	-9.53	0.09*	3,948	4,425
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	3.44	-1.33	0.42	5.15	1.72	0.48	-3.04	0.26	3,948	4,425
Average hours per day children (age 5 to 14) spend studying at night	0.16	0.09	0.43	0.40	-0.02	0.46	0.11	0.34	2,628	3,003
Fraction of youth age 15 to 24 with health problems in last 7 days[a]	0.28	0.01	0.89	0.26	-0.01	0.38	0.03	0.76	2,261	2,628
Fraction of children age 5 to 14 with health problems in last 7 days[a]	0.24	0.06	0.43	0.29	0.00	0.77	0.05	0.47	3,020	3,397
Household operates any IGA	0.64	0.04	0.60	0.63	0.01	0.75	0.03	0.65	3,948	4,425
Annual household nonelectricity consumption (TZS)	3,289,482	-1,093,593	0.07	3,430,744	-96,410	0.44	-997,183	0.09*	3,564	3,968

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for lagged (baseline) outcome when available. The analysis sample includes a total of 235 households with head aged under 25 (122 comparison and 113 intervention), and 8,138 households with head aged 25 or over (4,303 comparison and 3,835 intervention). Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. Sample size for outcomes related to children reflect households with children. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Health problems include headaches; vision and respiratory problems.

/**/** The difference in the estimated impacts for the subgroups is significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Table E.2d. Household-level T&D lines impacts: Subgroup results by urban-rural location

	Urban			Rural					Sample size	
	Comparison mean	Impact	*p*-value	Comparison mean	Impact	*p*-value	Difference in impacts	*p*-value of difference in impacts	Intervention	Comparison
Household is connected to national grid	0.20	0.13	0.00	0.06	0.09	0.00	0.04	0.31	4,466	4,430
Monthly amount of electricity used by household from any source (kWh)	24.90	4.61	0.22	14.81	1.51	0.43	3.10	0.48	4,466	4,430
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	6.38	3.90	0.20	4.86	1.08	0.76	2.83	0.57	4,466	4,430
Average hours per day children (age 5 to 14) spend studying at night	0.53	-0.11	0.03	0.32	0.03	0.35	-0.14	0.01**	2,899	3,007
Fraction of youth age 15 to 24 with health problems in last 7 days[a]	0.28	-0.05	0.06	0.25	0.01	0.78	-0.06	0.09*	2,514	2,632
Fraction of children age 5 to 14 with health problems in last 7 days[a]	0.29	0.01	0.82	0.29	0.00	0.84	0.00	0.95	3,334	3,402
Household operates any IGA	0.69	0.01	0.69	0.59	0.00	0.85	0.01	0.84	4,466	4,430
Annual household nonelectricity consumption (TZS)	4,043,588	83,986	0.74	3,107,531	-201,554	0.19	285,539	0.36	4,036	3,972

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for lagged (baseline) outcome when available. The analysis sample includes a total of 2,658 urban households (1,603 comparison and 1,055 intervention) and 6,239 rural households (2,827 comparison and 3,412 intervention). Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. Sample size for outcomes related to children reflect households with children. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Health problems include headaches, vision and, respiratory problems.

/**/** The difference in the estimated impacts for the subgroups is significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Table E.2e. Household-level T&D lines impacts: Subgroup results by baseline income quartile

	First quartile (360,000 TZS or less)		Second quartile (360,001 TZS–1,070,000 TZS)		Third quartile (1,070,001 TZS–2,435,000 TZS)		Fourth quartile (greater than 2,435,000 TZS)			
	Impact	*p*-value	Impact	*p*-value	Impact	*p*-value	Impact	*p*-value	*p*-value of joint significance test	Sample size
Household is connected to national grid	0.05	0.00	0.07	0.00	0.12	0.00	0.18	0.00	0.00***	8,896
Monthly amount of electricity used by household from any source (kWh)	0.54	0.74	3.89	0.02	6.55	0.02	0.38	0.93	0.14	8,896
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	0.49	0.71	0.51	0.68	-0.11	0.96	7.53	0.27	0.72	8,896
Average hours per day children (age 5 to 14) spend studying at night	-0.03	0.50	-0.01	0.82	0.01	0.90	-0.04	0.33	0.78	5,906
Fraction of youth age 15 to 24 with health problems in last 7 days[a]	-0.02	0.56	-0.03	0.31	0.00	0.89	-0.02	0.49	0.85	5,146
Fraction of children age 5 to 14 with health problems in last 7 days[a]	-0.02	0.51	0.01	0.74	0.02	0.50	0.01	0.74	0.76	6,736
Household operates any IGA	-0.01	0.61	0.04	0.09	0.02	0.44	-0.02	0.49	0.18	8,896
Annual household nonelectricity consumption (TZS)	-76,586	0.63	-290,264	0.07	110,937	0.63	-90,424	0.78	0.53	8,008

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for lagged (baseline) outcome when available. The analysis sample includes 1,039 comparison and 1,258 intervention households in the first quartile; 990 comparison and 1,075 intervention households in the first second quartile; 1,238 comparison and 1,090 intervention households in the third quartile; and 1,163 comparison and 1,044 intervention households in the fourth quartile. Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. Sample size for outcomes related to children reflect households with children. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Health problems include headaches; vision and respiratory problems.

/**/** The difference in the estimated impacts for the subgroups are jointly significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Table E.3a. FS impacts: Full analysis sample

Household outcome at follow-up	Treatment mean	Control mean	Impact	*p*-value	Sample size
Connection rate domain					
Primary outcome					
Household is connected to national grid	0.31	0.18	0.13***	0.00	4,466
Secondary outcomes					
Household is connected to MCC lines	0.20	0.08	0.12***	0.00	4,449
Household is connected to non-MCC lines built after 2011	0.07	0.07	0.00	0.95	4,449
Household is connected to non-MCC lines built before 2011	0.04	0.03	0.02	0.12	4,449
Household is with access to grid without additional poles	0.63	0.48	0.15***	0.00	4,466
Household is within 30 meters of nearest electric pole (GPS data)	0.41	0.30	0.11*	0.04	4,367
Household is within 30 meters of nearest electric pole (household listing data)	0.56	0.42	0.14**	0.01	4,051
Household is within 30 meters of nearest electric pole (household survey data)	0.55	0.41	0.14***	0.00	4,466
Household is within 40 meters of nearest electric pole (GPS data)	0.49	0.39	0.10	0.12	4,367
Household is within 40 meters of nearest electric pole (household survey data)	0.64	0.48	0.16***	0.00	4,466
Household is within 50 meters of nearest electric pole (GPS data)	0.56	0.44	0.11	0.12	4,367
Household is within 50 meters of nearest electric pole (household survey data)	0.70	0.53	0.17***	0.00	4,466
Household is within 100 meters of nearest electric pole (GPS data)	0.66	0.57	0.09	0.23	4,367
Household is within 100 meters of nearest electric pole (household survey data)	0.85	0.67	0.18***	0.00	4,452
Average years household has been connected to national grid[a]	0.71	0.43	0.28***	0.00	4,420
Average hours per day household has grid electricity[a]	4.69	2.90	1.79***	0.00	4,466
Energy use domain					
Primary outcome					
Monthly amount of electricity used by household from any source (kWh)	26.93	20.32	6.61**	0.01	4,466
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	11.16	6.61	4.55	0.53	4,466
Secondary outcomes					
Household uses electricity from any source except batteries	0.36	0.28	0.08***	0.00	4,466
Household owns a generator powered by liquid fuel/solar/hydro/wind	0.18	0.24	-0.06**	0.01	4,466
Monthly amount of grid electricity used by household (kWh)	24.78	15.22	9.56***	0.00	4,466
Monthly amount of nongrid electricity used by household (kWh)	2.47	5.24	-2.77**	0.03	4,466
Monthly amount of kerosene used by household (liter)	1.77	1.33	0.44	0.17	4,466
Monthly amount of solid fuel used by household (kg)	131.88	151.32	-19.44	0.22	4,466
Number of electric tools/appliances owned by household	4.70	3.99	0.72***	0.00	4,466
Household owns a television	0.26	0.21	0.05***	0.00	4,466
Monthly hours of electric tools/appliances used by household	782	564	217***	0.00	4,466
Monthly hours of electric fan used by household	4.62	3.00	1.62	0.40	4,466
Monthly amount of light consumed by household (lumen-hours)	415,418	286,086	129,332***	0.00	4,466
Total monthly cost of light consumed by household (TZS)	4078	1598	2479*	0.09	4,440
Household owns at least one mobile phone	0.86	0.84	0.01	0.47	4,466
Monthly household costs for mobile phone recharge (TZS)	1500	2040	-540***	0.00	4,458

Table E.3a. (*continued*)

Household outcome at follow-up	Treatment mean	Control mean	Impact	*p*-value	Sample size
Education and child time use domain					
Primary outcome					
Average hours per day children (age 5 to 14) spend studying at night[b]	0.37	0.35	0.02	0.69	2,899
Secondary outcomes					
Average hours per day children (age 5 to 14) spend in total studying	0.64	0.64	0.00	0.98	2,899
Average hours per day youth (age 15 to 24) spend studying at night	1.26	1.31	-0.05	0.70	875
Average hours per day youth (age 15 to 24) spend in total studying	1.61	1.77	-0.17	0.09	875
Hours children spent collecting water and fuel in last 24 hours	0.95	0.83	0.12	0.15	2,800
Hours children spent performing other household chores in last 24 hours	0.63	0.64	0.00	0.96	2,800
Hours children spent on leisure/entertainment in last 24 hours	2.23	2.33	-0.11	0.56	2,800
Hours children spent watching television in last 24 hours[c]	0.54	0.36	0.18***	0.00	2,800
Hours children spent sleeping at night in last 24 hours	9.28	9.22	0.05	0.53	2,800
Fraction of children in household age 5 to 14 attending school	0.76	0.78	-0.01	0.66	3,334
Household has a child age 5 to 14 attending a school with electricity	0.26	0.22	0.04	0.49	3,334
Health and safety domain					
Primary outcome					
Fraction of youth age 15 to 24 in household with health problems in last 7 days[d]	0.30	0.24	0.07**	0.01	2,514
Fraction of children age 5 to 14 in household with health problems in last 7 days[d]	0.35	0.28	0.07***	0.01	3,334
Secondary outcomes					
Household has a member ages 15 to 24 missed work in the last 30 days due to illness	0.23	0.16	0.06*	0.08	2,411
Monthly amount of internal pollution from soot (grams of black carbon)	180.44	171.17	9.27	0.87	4,466
Monthly amount of external pollution from carbon (kg CO2)	265.14	280.42	-15.28	0.65	4,466
Household received family planning information from television/radio/internet/phone in last 30 days	0.42	0.45	-0.03	0.46	4,466
Household survey respondent currently uses family planning method	0.34	0.32	0.02	0.46	3,787
Household received HIV info from TV/radio/internet/phone in last 30 days	0.42	0.44	-0.02	0.69	4,466
Household has ever visited an electrified hospital at night	0.36	0.33	0.03	0.43	4,466
Respondent feels safe at night by all measures of safety [e]	0.17	0.12	0.05**	0.05	4,466
Respondent feels safe at night by at least one measure of safety[e]	0.86	0.80	0.07**	0.02	4,466
Respondent feels safe at night by more than half of the measures of safety[e]	0.63	0.47	0.16***	0.00	4,466
Household has had a major fire in home since 2011	0.03	0.04	0.00	0.95	4,466
Business and adult time use domain					
Primary outcome					
Household operates any income generating activities (IGA)	0.61	0.63	-0.02	0.34	4,466
Secondary outcomes					
Household operates an IGA that uses grid electricity	0.11	0.08	0.02	0.13	4,466
Household's monthly revenue from IGA (TZS)	229,480	164,434	65,046	0.23	3,757
Household's annual revenue from IGA (TZS)	1,870,799	1,755,975	114,823	0.85	3,857
Household has at least one member who is a paid employee	0.19	0.17	0.02	0.38	4,466
Women's time use: hours per day on each type of activity					
Wage labor (agricultural and nonagricultural)	0.93	0.71	0.22**	0.04	4,017

Table E.3a. (*continued*)

Household outcome at follow-up	Treatment mean	Control mean	Impact	*p*-value	Sample size
Nonwage labor/other productive activities (farming and other activities)	1.06	1.04	0.02	0.88	4,017
Other IGA	1.26	1.27	-0.01	0.96	4,017
Household chores and child care	2.44	2.41	0.03	0.82	4,017
Collecting fuel and water	1.33	1.42	-0.09	0.46	4,017
Cooking, processing, and preparing food	3.50	3.34	0.16	0.12	4,017
Reading and studying	0.06	0.03	0.03**	0.04	4,017
Socializing and resting	4.37	4.67	-0.30	0.16	4,017
Spending time at home with family	2.39	2.24	0.15	0.40	4,017
Watching television[c]	0.42	0.32	0.10***	0.00	4,017
Sleeping at night	8.53	8.66	-0.13**	0.03	4,017
Men's time use: hours per day on each type of activity					
Wage labor (agricultural and nonagricultural)	2.00	1.61	0.40**	0.04	3,101
Nonwage labor/other productive activities (farming and other activities)	1.35	1.41	-0.06	0.73	3,101
Other IGA	1.70	1.73	-0.03	0.85	3,101
Household chores and child care	0.55	0.46	0.10	0.24	3,101
Collecting fuel and water	0.65	0.54	0.11	0.34	3,101
Cooking, processing, and preparing food	0.26	0.27	-0.01	0.86	3,101
Reading and studying	0.12	0.09	0.03	0.39	3,101
Socializing and resting	5.69	5.86	-0.17	0.50	3,101
Spending time at home with family	2.03	2.05	-0.02	0.86	3,101
Watching television[c]	0.58	0.44	0.14*	0.06	3,101
Sleeping at night	8.22	8.49	-0.27**	0.02	3,101
Economic well-being domain					
Primary outcome					
Annual household nonelectricity consumption (TZS)	3,634,511	3,199,536	434,975	0.15	4,036
Secondary outcomes					
Annual household income (TZS)	3,223,456	2,800,947	422,508	0.52	3,679
Household per capita daily consumption (TZS)	2,221	1,857	365***	0.00	4,036
Household per capita daily income (TZS)	1,937	1,557	381	0.33	3,679
Household consumes less than $1 per day per person	0.69	0.75	-0.06***	0.01	4,036
Household consumes less than $2 per day per person	0.91	0.93	-0.03***	0.01	4,036
Total household assets (TZS)	21,048,558	48,467,524	-27,418,966	0.11	3,562
Household has an electrifiable dwelling based on wall and roof materials	0.76	0.75	0.01	0.67	4,466
Average number of rooms in household for sleeping	3.54	3.73	-0.19	0.40	4,466
Household has a flush toilet	0.21	0.21	0.00	0.97	4,466
Household has piped water in rainy and dry season	0.05	0.06	-0.01	0.74	4,466
Composition and mobility					
Primary outcomes					
Number of households in community (based on household listing)[f]	235.69	253.63	-17.94	0.24	177
Secondary outcomes					
Fraction of households in community at follow-up who are in-migrants since 2011[f]	0.02	0.02	0.00	0.73	177

Table E.3a. (*continued*)

Household outcome at follow-up	Treatment mean	Control mean	Impact	*p*-value	Sample size
Fraction of households in community at follow-up who are newly formed since 2011[f]	0.01	0.01	0.00	0.30	177
Household moved within community since 2011	0.13	0.09	0.03	0.12	4,033
Baseline household migrated out since 2011	0.02	0.03	-0.01	0.59	4,466
Household out-migrated since 2011 and was among those with baseline income above district median	0.02	0.04	-0.02	0.35	2,307
Households out-migrated since 2011 and was among those with baseline income below district median	0.02	0.02	0.00	0.75	1,847

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for lagged (baseline) outcome when available. The analysis sample includes a total of 4,467 households with 632 in the treatment group and 3,855 in the control group. Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] The average includes households that were not connected to the national grid.

[b] Parents were asked how many hours per day each child spends studying during the day and at night, and these numbers were averaged across all children of that age in the household. For other activities, parents were simply asked how much time one specific child age 5-14 spent on that activity during the past 24 hours.

[c] Time children spent watching television is a component of the measure of time they spent on leisure/entertainment; for adults (women and men), time spent at home with family and watching television are components of the measure of time spent on socializing and resting.

[d] Health problems include headaches; vision and respiratory problems.

[e] The measures of perceived safety are based on four items in the follow-up household survey covering whether communal lights around households and businesses are sufficient to help walk at night, whether the respondent feels safe walking in the community at night, and whether lights in the community provide some protection against crime and wild animals.

[f] This outcome is a community-level aggregate based on follow-up household listing data, which covers households in the subvillage where the household survey was conducted (but not other subvillages covered by the community survey). Statistics on the first two secondary outcomes in this domain are weighted by the number of in-migrant/newly formed households present at follow-up.***/**/***** Impact estimate is significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

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

Table E.3b. FS impacts: Subgroup results by gender of household head

	Female-headed households			Male-headed households					Sample size	
	Control mean	Impact	*p*-value	Control mean	Impact	*p*-value	Difference in impacts	*p*-value of difference in impacts	Treatment	Control
Household is connected to national grid	0.13	0.17	0.00	0.20	0.12	0.00	0.06	0.24	576	3,378
Monthly amount of electricity used by household from any source (kWh)	13.25	8.68	0.05	22.04	5.85	0.03	2.83	0.54	576	3,378
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	1.39	0.93	0.46	6.96	7.44	0.46	-6.51	0.52	576	3,378
Average hours per day children (age 5 to 14) spend studying at night	0.31	0.09	0.26	0.37	-0.01	0.89	0.10	0.31	373	2,260
Fraction of youth age 15 to 24 with health problems in last 7 days[a]	0.26	0.08	0.15	0.23	0.07	0.01	0.01	0.84	337	1,929
Fraction of children age 5 to 14 with health problems in last 7 days[a]	0.29	0.11	0.02	0.29	0.05	0.05	0.05	0.29	449	2,576
Household operates any IGA	0.55	0.00	0.93	0.66	-0.02	0.38	0.03	0.54	576	3,378
Annual household nonelectricity consumption (TZS)	2,382,972	346,197	0.24	3,486,125	503,725	0.19	-157,528	0.56	522	3,047

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for lagged (baseline) outcome when available. The analysis sample includes a total of 947 households with a female head (795 control and 152 treatment), and 3,007 households with a male head (2,583 control and 424 treatment). Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. Sample size for outcomes related to children reflect households with children. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Health problems include headaches; vision and respiratory problems.

/**/** The difference in the estimated impacts for the subgroups is significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Table E.3c. FS impacts: Subgroup results by age of household head

	Households with head under age 25			Households with head over age 25					Sample size	
	Control mean	Impact	*p*-value	Control mean	Impact	*p*-value	Difference in impacts	*p*-value of difference in impacts	Treatment	Control
Household is connected to national grid	0.13	0.00	0.99	0.18	0.13	0.00	-0.13	0.20	576	3,372
Monthly amount of electricity used by household from any source (kWh)	9.21	16.23	0.15	20.34	6.30	0.01	9.94	0.38	576	3,372
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	1.89	1.20	0.62	5.78	5.94	0.44	-4.74	0.50	576	3,372
Average hours per day children (age 5 to 14) spend studying at night	0.20	0.24	0.48	0.36	0.01	0.85	0.23	0.50	373	2,255
Fraction of youth age 15 to 24 with health problems in last 7 days[a]	0.27	0.18	0.47	0.23	0.07	0.01	0.11	0.65	337	1,924
Fraction of children age 5 to 14 with health problems in last 7 days[a]	0.28	0.06	0.69	0.29	0.07	0.01	0.00	0.98	449	2,571
Household operates any IGA	0.67	0.05	0.68	0.63	-0.02	0.51	0.07	0.62	576	3,372
Annual household nonelectricity consumption (TZS)	2,175,475	800,180	0.07	3,257,020	453,751	0.19	346,429	0.36	522	3,042

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for lagged (baseline) outcome when available. The analysis sample includes a total of 113 households with head aged under 25 (99 control and 14 treatment), and 3,835 households with head aged 25 or over (3,273 control and 562 treatment). Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. Sample size for outcomes related to children reflect households with children. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Health problems include headaches; vision and respiratory problems.

/**/** The difference in the estimated impacts for the subgroups is significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Table E.3d. FS impacts: Subgroup results by urban-rural location

	Urban			Rural					Sample size	
	Control mean	Impact	*p*-value	Control mean	Impact	*p*-value	Difference in impacts	*p*-value of difference in impacts	Treatment	Control
Household is connected to national grid	0.33	0.10	0.09	0.13	0.15	0.00	-0.05	0.43	632	3,834
Monthly amount of electricity used by household from any source (kWh)	30.91	7.31	0.20	16.74	6.37	0.03	0.95	0.88	632	3,834
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	10.53	-0.10	0.98	5.28	6.20	0.54	-6.30	0.60	632	3,834
Average hours per day children (age 5 to 14) spend studying at night	0.42	-0.09	0.27	0.33	0.05	0.37	-0.13	0.17	403	2,496
Fraction of youth age 15 to 24 with health problems in last 7 days[a]	0.21	0.07	0.19	0.24	0.07	0.04	0.00	0.99	359	2,155
Fraction of children age 5 to 14 with health problems in last 7 days[a]	0.30	0.03	0.49	0.28	0.08	0.01	-0.05	0.28	481	2,853
Household operates any IGA	0.70	-0.03	0.49	0.61	-0.02	0.48	-0.01	0.81	632	3,834
Annual household nonelectricity consumption (TZS)	4,065,389	-208,928	0.63	2,927,563	641,600	0.06	-850,528	0.12	573	3,463

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for lagged (baseline) outcome when available. The analysis sample includes a total of 1,055 urban households (1,603 control and 1,055 treatment), and 3,412 rural households (2,827 control and 3,412 treatment). Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. Sample size for outcomes related to children reflect households with children. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Health problems include headaches; vision and respiratory problems.

*/**/*** The difference in the estimated impacts for the subgroups is significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Table E.3e. FS impacts: Subgroup results by baseline income quartile

	First quartile (360,000 TZS or less)		Second quartile (360,001 TZS–1,070,000 TZS)		Third quartile (1,070,001 TZS–2,435,000 TZS)		Fourth quartile (greater than 2,435,000 TZS)			
	Impact	*p*-value	Impact	*p*-value	Impact	*p*-value	Impact	*p*-value	*p*-value of joint significance test	Sample size
Household is connected to national grid	0.08	0.05	0.13	0.00	0.20	0.00	0.13	0.00	0.13	4,466
Monthly amount of electricity used by household from any source (kWh)	2.02	0.46	4.37	0.30	12.03	0.02	7.14	0.05	0.21	4,466
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	1.56	0.48	0.05	0.96	0.80	0.61	14.08	0.58	0.74	4,466
Average hours per day children (age 5 to 14) spend studying at night	0.04	0.46	-0.01	0.81	0.00	0.97	0.05	0.50	0.74	2,899
Fraction of youth age 15 to 24 with health problems in last 7 days[a]	0.07	0.23	0.09	0.08	0.05	0.24	0.06	0.06	0.94	2,514
Fraction of children age 5 to 14 with health problems in last 7 days[a]	0.07	0.31	0.09	0.03	0.00	0.98	0.10	0.01	0.22	3,334
Household operates any IGA	-0.05	0.29	0.01	0.77	0.02	0.58	-0.07	0.14	0.19	4,466
Annual household nonelectricity consumption (TZS)	159,899	0.48	222,544	0.43	736,359	0.17	522,417	0.34	0.67	4,036

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for lagged (baseline) outcome when available. The analysis sample 1,079 control and 179 treatment households in the first quartile; 913 control and 162 treatment households in the first second quartile; 940 control and 150 treatment households in the third quartile; and 903 control and 141 treatment households in the fourth quartile. Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. Sample size for outcomes related to children reflect households with children. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Health problems include headaches; vision and respiratory problems.

/**/** The difference in the estimated impacts for the subgroups are jointly significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Table E.3f. FS impacts: Kigoma versus non-Kigoma regions

	Kigoma			Non-Kigoma					Sample size	
	Control mean	Impact	*p*-value	Control mean	Impact	*p*-value	Difference in impacts	*p*-value of difference in impacts	Treatment	Control
Household is connected to national grid	0.39	-0.15	0.19	0.18	0.13	0.00	-0.28	0.02**	661	4,249
Monthly amount of electricity used by household from any source (kWh)	33.58	-14.97	0.08	20.32	6.61	0.01	-21.58	0.02**	661	4,249
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	3.15	-2.35	0.09	6.61	4.55	0.53	-6.91	0.35	661	4,249
Average hours per day children (age 5 to 14) spend studying at night	0.33	-0.17	0.15	0.35	0.02	0.68	-0.18	0.14	422	2,781
Fraction of youth age 15 to 24 with health problems in last 7 days[a]	0.17	0.01	0.86	0.24	0.07	0.01	-0.06	0.15	382	2,456
Fraction of children age 5 to 14 with health problems in last 7 days[a]	0.23	0.14	0.00	0.28	0.07	0.01	0.07	0.12	504	3,159
Household operates any IGA	0.65	-0.03	0.54	0.63	-0.02	0.34	-0.01	0.92	661	4,249
Annual household nonelectricity consumption (TZS)	3,549,174	-354,135	0.48	3,199,546	434,975	0.15	-789,110	0.18	596	3,786

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for lagged (baseline) outcome when available. The analysis sample includes a total of 661 Kigoma households (415 control and 29 treatment), and 4,249 non-Kigoma households (3,834 control and 632 treatment). Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. Sample size for outcomes related to children reflect households with children. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Health problems include headaches; vision and respiratory problems.

*/**/*** The difference in the estimated impacts for the subgroups are jointly significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Table E.4a. Impacts of connection to grid electricity: Full analysis sample

Community outcome at follow-up	Connected mean	Non-connected mean	Impact	*p*-value	Sample size
Energy use domain					
Primary outcome					
Monthly amount of electricity used by household from any source (kWh)	82.66	12.22	70.44***	0.00	8,771
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	12.30	9.35	2.95	0.48	8,771
Secondary outcomes					
Household uses electricity from any source except batteries	1.01	0.22	0.79***	0.00	8,771
Household owns a generator powered by liquid fuel/solar/hydro/wind	0.21	0.36	-0.14***	0.00	8,771
Monthly amount of grid electricity used by household (kWh)	83.84	0.03	83.81***	0.00	8,712
Monthly amount of nongrid electricity used by household (kWh)	3.14	12.18	-9.04***	0.00	8,771
Monthly amount of kerosene used by household (liter)	0.90	2.27	-1.37***	0.00	8,771
Monthly amount of solid fuel used by household (kg)	126.39	138.35	-11.97	0.23	8,771
Number of electric tools/appliances owned by household	11.69	3.86	7.84***	0.00	8,771
Household owns a television	0.77	0.22	0.56***	0.00	8,771
Monthly hours of electric tools/appliances used by household	2,020.87	438.52	1582.35***	0.00	8,771
Monthly hours of electric fan used by household	14.42	0.55	13.87***	0.00	8,771
Monthly amount of light consumed by household (lumen-hours)	1,153,687	190,922	962,765***	0.00	8,771
Total monthly cost of light consumed by household (TZS)	-1,979	12,960	-14,939	0.19	8,734
Household owns at least one mobile phone	0.98	0.93	0.04***	0.00	8,771
Monthly household costs for mobile phone recharge (TZS)	-51.06	3107	-3158***	0.00	8,749
Education and child time use domain					
Primary outcome					
Average hours per day children (age 5 to 14) spend studying at night [a]	0.60	0.41	0.20***	0.00	5,824
Secondary outcomes					
Average hours per day children (age 5 to 14) spend in total studying	0.95	0.71	0.23***	0.00	5,824
Average hours per day youth (age 15 to 24) spend studying at night	1.67	1.38	0.29***	0.00	1,805
Average hours per day youth (age 15 to 24) spend in total studying	2.08	1.85	0.23***	0.01	1,805
Hours children spent collecting water and fuel in last 24 hours	0.55	0.70	-0.15***	0.00	5,591
Hours children spent doing other household chores in last 24 hours	0.54	0.60	-0.06	0.10	5,591
Hours children spent on leisure/entertainment in last 24 hours	3.38	2.11	1.27***	0.00	5,591
Hours children spent watching television in last 24 hours[b]	1.45	0.24	1.21***	0.00	5,591
Hours children spent sleeping at night in last 24 hours	9.17	9.12	0.05	0.26	5,591
Fraction of children in household age 5 to 14 attending school	0.85	0.83	0.02*	0.06	6,636
Health and safety domain					
Primary outcome					
Fraction of youth age 15 to 24 with health problems in last 7 days[c]	0.25	0.24	0.00	0.86	5,072
Fraction of children age 5 to 14 with health problems in last 7 days[c]	0.30	0.28	0.02	0.14	6,636
Secondary outcomes					
Household has a member ages 15 to 24 who missed work in the last 30 days due to illness	0.16	0.18	-0.02	0.31	4,833
Monthly amount of internal pollution from soot (grams of black carbon)	185.51	165.21	20.88	0.52	8,771

Table E.4a. (*continued*)

Community outcome at follow-up	Connected mean	Non-connected mean	Impact	*p*-value	Sample size
Monthly amount of external pollution from carbon (kg CO2)	272.19	275.52	-3.33	0.86	8,771
Household received family planning info from TV/radio/internet/phone in last 30 days	0.63	0.52	0.10***	0.00	8,771
Household survey respondent currently uses family planning method	0.35	0.38	-0.03	0.12	7,431
Household received HIV info from TV/radio/internet/phone in last 30 days	0.61	0.51	0.10***	0.00	8,771
Household had a major fire in home since 2011	0.03	0.03	0.00	0.50	8,771
Household had a fire caused by electric source since 2011	0.0034	0.0001	0.0032*	0.06	8,771
Household had a fire caused by nonelectric source since 2011	0.03	0.03	-0.01	0.21	8,771
Business and adult time use domain					
Primary outcome					
Household operates any income generating activities (IGA)	0.73	0.71	0.02	0.13	8,771
Secondary outcomes					
Household operates any IGA that uses grid electricity	0.26	0.09	0.17***	0.00	8,771
Household's monthly revenue from IGA (TZS)	338,234	213,962	124,272***	0.00	7,506
Household's annual revenue from IGA (TZS)	3,694,121	2,016,636	1,677,484***	0.01	7,606
Household has at least one member who is a paid employee	0.28	0.25	0.02	0.15	8,771
Women's time use: hours per day on each type of activity					
Wage labor (agricultural and nonagricultural)	1.02	0.92	0.10	0.34	7,930
Nonwage labor/other productive activities (farming and other activities)	0.83	0.85	-0.02	0.73	7,930
Other income generating activities	1.56	1.55	0.00	0.99	7,930
Household chores and child care	2.48	2.46	0.02	0.76	7,930
Collecting fuel and water	0.86	1.12	-0.26***	0.00	7,930
Cooking, processing, and preparing food	3.29	3.39	-0.10	0.16	7,930
Reading and studying	0.07	0.05	0.02	0.39	7,930
Socializing and resting	5.84	4.64	1.21***	0.00	7,930
Time spent at home with family[b]	2.26	2.15	0.10	0.21	7,930
Watching television[b]	1.36	0.21	1.15***	0.00	7,930
Sleep at night	8.49	8.51	-0.01	0.75	7,930
Men's time use: hours per day on each type of activity					
Wage labor (agricultural and nonagricultural)	1.78	1.91	-0.13	0.41	6,129
Nonwage labor/other productive activities (farming and other activities)	1.17	1.31	-0.14	0.21	6,129
Other income generating activities	2.04	2.08	-0.04	0.82	6,129
Household chores and child care	0.40	0.44	-0.04	0.29	6,129
Collecting fuel and water	0.29	0.39	-0.10**	0.02	6,129
Cooking, processing, and preparing food	0.19	0.27	-0.08***	0.01	6,129
Reading and studying	0.16	0.11	0.05*	0.10	6,129
Socializing and resting	6.85	5.77	1.08***	0.00	6,129
Time spent at home with family[b]	2.01	1.90	0.11	0.13	6,129
Watching television[b]	1.52	0.34	1.18***	0.00	6,129
Sleep at night	8.30	8.35	-0.05	0.35	6,129

Table E.4a. (*continued*)

Community outcome at follow-up	Connected mean	Non-connected mean	Impact	*p*-value	Sample size
Economic well-being domain					
Primary outcome					
Annual household nonelectricity consumption (TZS)	5,282,912	4,158,205	1,124,708***	0.00	7,898
Secondary outcomes					
Annual household income (TZS)	5,993,702	4,026,342	1,967,360**	0.01	7,245
Household per capita daily consumption (TZS)	2,935	2,370	564***	0.00	7,898
Household per capita daily income (TZS)	3,033	2,400	633*	0.07	7,245
Household consumes less than $1 per day per person	0.50	0.66	-0.16***	0.00	7,898
Household consumes less than $2 per day per person	0.85	0.90	-0.05***	0.00	7,898
Total household assets (TZS)	85,594,850	61,659,737	21,935,113	0.70	6,931
Average number of rooms in household for sleeping	3.97	3.91	0.06***	0.00	8,771
Household has a flush toilet	0.51	0.29	0.22***	0.00	8,771
Household has piped water in rainy and dry season	0.16	0.09	0.07***	0.00	8,771

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for lagged (baseline) outcome when available. The analysis sample includes a total of 8,897 households with 1,189 in the connected group and 7,629 in the non-connected group. Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Parents were asked how many hours per day each child spends studying during the day and at night, and these numbers were averaged across all children of that age in the household. For other activities, parents were simply asked how much time one specific child age 5-14 spent on that activity during the past 24 hours.

[b] Time children spent watching television is a component of the measure of time they spent on leisure/entertainment; for adults (women and men), time spent at home with family and watching television are components of the measure of time spent on socializing and resting.

[c] Health problems include headaches; vision and respiratory problems.

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

Table E.4b. Impacts of connection to grid electricity: Subgroup results by gender of household head

	Female-headed households			Male-headed households					Sample size	
	Non-connected mean	Impact	*p*-value	Non-connected mean	Impact	*p*-value	Difference in impacts	*p*-value of difference in impacts	Connected	Non-connected
Monthly amount of electricity used by household from any source (kWh)	4.85	73.33	0.00	14.70	68.40	0.00	4.93	0.42	1,085	7,174
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	3.15	1.94	0.42	9.87	3.79	0.49	-1.85	0.75	1,085	7,174
Average hours per day children (age 5 to 14) spend studying at night	0.43	0.22	0.01	0.41	0.20	0.00	0.02	0.83	779	4,779
Fraction of youth age 15 to 24 with health problems in last 7 days[a]	0.29	0.03	0.51	0.23	0.01	0.75	0.02	0.62	746	4,078
Fraction of children age 5 to 14 with health problems in last 7 days[a]	0.27	0.05	0.25	0.28	0.02	0.33	0.03	0.53	858	5,469
Household operates any IGA	0.65	0.01	0.70	0.72	0.03	0.14	-0.01	0.78	1,085	7,174
Annual household nonelectricity consumption (TZS)	3,536,412	740,446	0.08	4,434,895	1,130,183	0.00	-389,736	0.45	880	6,551

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for lagged (baseline) outcome when available. The analysis sample includes a total of 1,933 female headed households (1,727 non-connected and 206 connected) and 6,326 male headed households (5,447 non-connected and 879 connected). Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. Sample size for outcomes related to children reflect households with children. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Health problems include headaches; vision and respiratory problems.

/**/** The difference in the estimated impacts for the subgroups is significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Table E.4c. Impacts of connection to grid electricity: Subgroup results by age of household head

	Households with head under age 25			Households with head over age 25					Sample size	
	Non-connected mean	Impact	*p*-value	Non-connected mean	Impact	*p*-value	Difference in impacts	*p*-value of difference in impacts	Connected	Non-connected
Monthly amount of electricity used by household from any source (kWh)	6.88	66.72	0.00	12.89	69.40	0.00	-2.68	0.80	1,085	7,163
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	4.08	-0.03	0.99	8.65	3.52	0.44	-3.55	0.56	1,085	7,163
Average hours per day children (age 5 to 14) spend studying at night	0.12	0.33	0.17	0.42	0.20	0.00	0.13	0.58	779	4,770
Fraction of youth age 15 to 24 with health problems in last 7 days[a]	0.22	-0.01	0.92	0.24	0.01	0.55	-0.02	0.86	746	4,069
Fraction of children age 5 to 14 with health problems in last 7 days[a]	0.25	-0.03	0.78	0.28	0.02	0.13	-0.06	0.64	858	5,459
Household operates any IGA	0.69	0.20	0.02	0.71	0.02	0.26	0.18	0.04**	1,085	7,163
Annual household nonelectricity consumption (TZS)	2,731,832	1,050,567	0.03	4,284,333	1,056,584	0.00	-6,018	0.99	880	6,542

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for lagged (baseline) outcome when available. The analysis sample includes a total of 229 households with head aged under 25 (203 non-connected and 26 connected), and 8,019 households with head aged 25 or over (6,960 non-connected and 1,059 connected). Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. Sample size for outcomes related to children reflect households with children. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Health problems include headaches; vision and respiratory problems.

/**/** The difference in the estimated impacts for the subgroups is significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Table E.4d. Impacts of connection to grid electricity: Subgroup results by urban-rural location

	Urban			Rural					Sample size	
	Non-connected mean	Impact	*p*-value	Non-connected mean	Impact	*p*-value	Difference in impacts	*p*-value of difference in impacts	Connected	Non-connected
Monthly amount of electricity used by household from any source (kWh)	10.44	75.24	0.00	13.80	65.77	0.00	9.46	0.03**	1,085	7,174
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	11.63	-2.85	0.08	7.34	8.60	0.27	-11.45	0.14	1,085	7,174
Average hours per day children (age 5 to 14) spend studying at night	0.45	0.23	0.00	0.37	0.17	0.00	0.06	0.32	779	4,779
Fraction of youth age 15 to 24 with health problems in last 7 days[a]	0.23	0.01	0.59	0.25	0.00	0.85	0.02	0.62	746	4,078
Fraction of children age 5 to 14 with health problems in last 7 days[a]	0.27	0.03	0.16	0.29	0.01	0.50	0.01	0.63	858	5,469
Household operates any IGA	0.73	0.01	0.73	0.69	0.04	0.06	-0.03	0.32	1,085	7,174
Annual household nonelectricity consumption (TZS)	4,351,564	1,224,293	0.00	3,994,015	1,032,131	0.00	192,163	0.65	880	6,551

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for lagged (baseline) outcome when available. The analysis sample includes a total of 2,470 urban households (1,932 non-connected and 538 connected) and 5,789 rural households (5,242 non-connected and 547 connected). Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. Sample size for outcomes related to children reflect households with children. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Health problems include headaches; vision and respiratory problems.

*/**/*** The difference in the estimated impacts for the subgroups is significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Table E.4e. Impacts of connection to grid electricity: Subgroup results by baseline income quartile

	First quartile (360,000 TZS or less)		Second quartile (360,001 TZS–1,070,000 TZS)		Third quartile (1,070,001 TZS–2,435,000 TZS)		Fourth quartile (greater than 2,435,000 TZS)			
	Impact	*p*-value	Impact	*p*-value	Impact	*p*-value	Impact	*p*-value	*p*-value of joint significance test	Sample size
Monthly mount of electricity used by household from any source (kWh)	68.57	0.00	76.31	0.00	70.64	0.00	68.51	0.00	0.72	8,771
Monthly amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)	2.25	0.43	1.76	0.48	2.56	0.33	3.13	0.70	0.99	8,771
Average hours per day children (age 5 to 14) spend studying at night	0.22	0.00	0.17	0.00	0.26	0.00	0.16	0.00	0.63	5,824
Fraction of youth age 15 to 24 with health problems in last 7 days[a]	-0.01	0.74	0.01	0.77	-0.01	0.81	0.02	0.50	0.85	5,072
Fraction of children age 5 to 14 with health problems in last 7 days[a]	0.02	0.60	0.03	0.44	0.03	0.39	0.02	0.51	0.99	6,636
Household operates any IGA	0.15	0.00	0.05	0.17	-0.01	0.71	-0.01	0.79	0.01***	8,771
Annual household nonelectricity consumption (TZS)	912,429	0.01	740,816	0.01	1,074,221	0.00	1,265,617	0.00	0.68	7,898

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for lagged (baseline) outcome when available. The analysis sample includes 1,073 non-connected and 584 connected households in the first quartile; 1,797 non-connected and 260connected households in the first second quartile; 2,108 non-connected and 198 connected households in the third quartile; and 2,021 non-connected and 147 connected households in the fourth quartile. Survey item-non-response may have resulted in smaller sample sizes for specific outcomes. Sample size for outcomes related to children reflect households with children. We calculated statistics using sample weights to account for sampling and interview non-response.

[a] Health problems include headaches; vision and respiratory problems.

/**/** The difference in the estimated impacts for the subgroups are jointly significantly different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

APPENDIX F

THE PROBLEM OF INACCURATE BASELINE GPS DATA AND ATTEMPTED ANALYTIC SOLUTIONS

This page has been left blank for double-sided copying.

We collected baseline GPS data of households for two reasons. First, we expected that the data would be helpful for locating the households at follow-up; in fact, they proved in general to be sufficiently accurate for this purpose.[95] Second, we expected to use the data to help us estimate impacts of gaining access to new lines. In particular, we hypothesized that households located within a 30-meter radius of the new electric poles would be far more likely to connect than those located just outside that 30-meter radius because TANESCO had a rule that made it generally far more expensive for households to connect if they lived beyond the 30-meter radius. Hence, to help identify impacts of access to new lines, we planned to compare outcomes for households located just inside the 30-meter radius to outcomes for households located just outside the 30-meter radius. Unfortunately, the baseline data were not sufficiently accurate for this purpose.[96] In this appendix, we describe the issue of inaccurate GPS data collected during the baseline household surveys conducted in 2011 and the analytic solutions that we attempted in order to fix the problem. This information might be useful for future studies that attempt to use the baseline GPS data in similar ways. The following analysis relied primarily on Stata statistical software for data cleaning, management, and analysis. Distance calculations used the user-generated command *geodist*. We used ArcGIS Desktop 10.2.2 to inspect the data visually at various stages and confirm that distance calculations and coordinate conversions performed in Stata were correct and that coordinate adjustment strategies performed as intended.

A. Geographic data

Coordinate data from the baseline household survey were available in the form of six separate variables that recorded latitudinal and longitudinal degrees, minutes, and seconds as positive integers of two, two, and three digits, respectively. Latitude was recorded in degrees, minutes, and seconds south, and longitude was recorded in degrees, minutes, and seconds east. We started with complete baseline GPS data for 10,015 households.

The follow-up data collection firm collected GPS data for households surveyed during the follow-up survey in 2015 and recorded the data in decimal degrees for both longitude and latitude.

B. Problems with baseline GPS data and solutions implemented

After the baseline data collection, the Mathematica evaluation team discovered several problems with the GPS data collection process. Below, we provide an overview of the problems and our efforts to resolve them. We had a greater degree of confidence in the follow-up

[95] We also had community-level GPS data that were helpful, though not always accurate. The household-level GPS data were particularly helpful for identifying subvillages within villages when community names or boundaries changed and when communities merged or split.

[96] As discussed in Appendix H, we used follow-up GPS data for that part of our analysis. The follow-up data were far more accurate but not ideal as many households moved between the follow-up and baseline, and some probably moved to be located within 30 meters of the new lines, meaning that their locations were no longer exogenous with respect to the availability of new lines. In Appendix H, we discuss how we tried to deal with that issue. Appendix H also describes some related work we did with the baseline GPS data that did not rely on the 30 meter rule but did make use of the fact that we expected a stronger relationship between distance from the line and connection rates for households shown as being within 40 meters of a line at baseline than for those farther from the line at baseline even with the errors described in this appendix.

locations, which were automatically recorded by the built-in remote sensing technology of the computer assisted personal interview (CAPI) devices and did not require manual recording or additional calculations. Therefore, as we set out to identify and resolve errors, all of the following solutions relied on the relationship between the baseline and follow-up locations of households included in both surveys.

1. Mixed reporting formats

Our review of the data indicated that baseline interviewers used two ways to record the GPS coordinates of households. Coordinates for some observations were recorded in degrees/minutes/seconds (DMS), where the three-digit number in the seconds variable represented the seconds value multiplied by 10 (for example, 143 is 14.3 seconds). For these observations, the value of the minutes variables was always less than 60. In other cases, the variables were reported as decimal degrees (DD), where the two-digit minutes variable and three-digit seconds variable represented decimal places following the degree. In these cases, the values of the minutes variables could range from 00 to 99.

Solution 1. Our review of the data suggested that most baseline observations were in DMS units. Therefore, Solution 1 focused on identifying observations that were likely in DD units and not in DMS units. We implemented the solution in two steps. First, if the minutes variables of either latitude or longitude were greater than or equal to 60, we assumed that the observation was in DD units because values of 60 or more cannot be DMS.[97] Second, we checked for inconsistencies within communities that appeared to suggest that some observations may have been recorded in DD units even though others (the majority) were typically recorded in DMS units. To do so, we looked for observations where the minutes variable of latitude or longitude was greater than 2 and differed by more than one minute (about 1.15 miles near the equator) in absolute value terms from the mode of the minutes variable by community. For such observations, we performed a comparison with the follow-up data and checked to see if the difference between the minutes variable from the baseline data and the first two decimal places of the follow-up DD coordinate was less than or equal to one in absolute value terms when both were converted to integers. For observations with minutes less than or equal to 2, we did not try to apply this fix.

According to the above criteria, approximately 7 percent of observations were eligible to be flagged as DD observations; the remaining 93 percent were inferred to be DMS observations. We then converted the DMS observations to decimal degrees according to the formulas in Table F.1.

[97] We could have also done something similar based on the seconds variable.

Table F.1. Examples of coordinates and calculation by type of observation

Observation type		D	M	S	Formula	Decimal degrees
DMS	Latitude	6	15	115	$-\left(D+\frac{M}{60}+\frac{S}{3600*10}\right)$	-6.253
	Longitude	32	26	463	$\left(D+\frac{M}{60}+\frac{S}{3600*10}\right)$	32.446
DD	Latitude	6	15	115	$-\left(SD+\frac{SM}{100}+\frac{SS}{100{,}000}\right)$	-6.151
	Longitude	32	26	463	$\left(SD+\frac{SM}{100}+\frac{SS}{100{,}000}\right)$	32.265

2. Typographical errors in the degree variable

In fewer than 1 percent of cases, the degrees variable for nonmoving households differed between baseline and follow-up, but the converted minutes and seconds, when converted to decimal degrees as described above, were close (within 0.1 degrees) to the corresponding value at follow-up. We define nonmoving households as those reporting in the follow-up survey that they neither moved to another community nor moved within their baseline community.

Solution 2. In these cases, we replaced the baseline degree of the household with its corresponding degree at follow-up, as the baseline degree records appeared to result from simple recording or typographical errors. However, if the degrees, minutes, and seconds of nonmoving households, when converted to decimal degrees, differed by 500 meters or more from follow-up coordinates and no apparent pattern explained the disparities, we set the locations to missing. After these adjustments, we reconverted all nonmissing observations to decimal degrees, according to the formulas in Table F.1.

3. Remaining disparities between baseline and follow-up location

Both visual inspection of preliminary maps and distance calculations revealed that widespread and important disparities remained between baseline and follow-up locations for nonmoving households in many communities; more than 55 percent of households fell further than 10 meters from their follow-up location; nearly 25 percent were at least 30 meters away. Moreover, visual inspection of these differences in location indicated that the differences tended to follow certain patterns by community.

Given our greater degree of confidence in the follow-up location data, we attempted two more solutions (3 and 4) that focused on nonmoving households, which we would expect to have the same coordinates at baseline and follow-up. We tested the effectiveness of the solutions by measuring the distances between the adjusted baseline location and the follow-up locations of nonmoving households.

Solution 3. When visual inspection indicated distinctive patterns of displacement by community (that is, all households appeared to move by about the same amount and in the same direction), we attempted to correct the baseline coordinates by using the following approach. We randomly selected a nonmoving household from each community and calculated the difference between the baseline and follow-up values of the latitudinal coordinates for that household and did the same for the longitudinal coordinates. Then, we applied the implied latitudinal and longitudinal adjustment to the baseline coordinates of all nonmoving households in the community and calculated the difference between the adjusted baseline and follow-up coordinates. However, after making the adjustment, we found that the distance between the adjusted baseline and follow-up locations was not meaningfully improved. In some cases, visual inspection showed that the randomly selected household was an outlier and that the adjustment process worsened baseline accuracy on average.

Solution 4. When Solution 3 did not prove adequate, we created interim maps and conducted additional visual analysis of the data. The analysis showed that errors in the baseline coordinates followed patterns specific to both the baseline interviewer and the community. In addition, we now had a way to make more precise adjustments over long distances than that allowed by the above formula. To account for these patterns, we used the trigonometric formula below to calculate the bearing between the baseline and follow-up coordinates, where lat_{bl} and $long_{bl}$ represent the baseline latitude and longitude, respectively, and lat_{fu} and $long_{fu}$ represent their counterparts at follow-up. The formula was adapted from Upadhyay (n.d.) and visually examined for accuracy by using ArcGIS:

$$Bearing = \tan^{-1}\left\{\begin{matrix}\left[\cos\left(lat_{fu}\right)*\sin\left(long_{fu}-long_{bl}\right)\right], \\ \left[\cos\left(lat_{bl}\right)*\sin\left(lat_{fu}\right)-\sin\left(lat_{bl}\right)*\cos\left(lat_{fu}\right)*\cos\left(long_{fu}-long_{bl}\right)\right]\end{matrix}\right\}$$

We also used *geodist* to calculate the distance between the baseline and follow-up locations. Next, we calculated the median distance and bearing between follow-up and baseline locations for nonmoving households by community and baseline interviewer ID (D_{med} and B_{med}, respectively).

We then used the user-generated Stata program *destpoint* and the median values to adjust the baseline coordinates of the household by the median distance along the median bearing. *Destpoint* applies the following formulas to the baseline latitude and longitude (converted to radians), where R is 6,371, the average radius of the earth, in kilometers, and $lat_{bl\,(revised)}$ and $long_{bl\,(revised)}$ are the latitude and longitude after adjustment (Picard 2011):

$$lat_{bl(revised)} = \sin^{-1}\left\{\begin{matrix}\left[\sin\left(lat_{bl}\right)*\cos\left(\frac{D_{med}}{R}\right)\right]+ \\ \left[\cos\left(lat_{bl}\right)*\sin\left(\frac{D_{med}}{R}\right)*\cos\left(B_{med}\right)\right]\end{matrix}\right\}$$

$$long_{bl(revised)} = long_{bl} + \tan^{-1}\left\{\begin{matrix}\left[\sin\left(B_{med}\right)*\sin\left(\frac{D_{med}}{R}\right)*\cos\left(lat_{bl}\right)\right], \\ \left[\cos\left(\frac{D_{med}}{R}\right)-\sin\left(lat_{bl}\right)*\sin\left(lat_{bl(revised)}\right)\right]\end{matrix}\right\}$$

Finally, we calculated the distance between the revised baseline locations and follow-up locations for nonmoving households. We found from both of these distance calculations, summarized in Table F.2, and from additional visual inspection that, even though the baseline accuracy for some communities improved, it was worsened for others. The first row of Table F.2 shows a general reduction in accuracy. Before adjustment, the baseline and follow-up locations of 43.8 percent of nonmoving households were within 10 meters of each other. After adjustment, the percentage dropped to 29.4 percent. The remaining rows of Table F.2 show results for sample communities. Ultimately, we concluded that the distances between the baseline and follow-up data both before and after adjustment were too large and that the true bearings were too varied to identify the location of households at baseline with adequate confidence.

Table F.2. Percentage of household baseline locations within given thresholds of follow-up locations before and after Solution 4 (selected illustrative communities; nonmoving households only)

		Before adjustment (percent of households)			After adjustment (percent of households)			
Type of community	Number of households	10 meters	20 meters	30 meters	10 meters	20 meters	30 meters	Solution 4 improved accuracy
Results for all nonmoving households with baseline and follow-up data								
All nonmoving households with complete GPS data at baseline and follow-up	7,012 [a]	43.8	69.7	76.7	29.4	56.4	67.7	No
Results by community for five sample communities								
High baseline accuracy	4 12	100.0 91.7	100.0 100.0	100.0 100.0	100.0 58.3	100.0 100.0	100.0 100.0	n.a. No
Moderate baseline accuracy	44	43.2	65.9	68.2	27.3	47.7	68.2	No
Low baseline accuracy	13 15	7.7 0.0	46.2 0.0	61.5 0.0	38.5 0.0	53.8 0.0	69.2 0.0	Yes No

Note: n.a. = not applicable.

[a] Restricted to nonmoving households with complete data at baseline and follow-up.

C. Conclusion

Despite the number of solutions applied, we were hampered by a lack of accurate or precise geographic coordinates to carry out further analysis with the baseline household GPS data.

This page has been left blank for double-sided copying.

APPENDIX G

WITHIN-STUDY COMPARISON DETAILS

This page has been left blank for double-sided copying.

The objective of a within-study comparison (WSC) is to investigate to what extent the results of a more rigorous research design—such as an RCT—may be replicated by less rigorous designs—such as those underlying non-experimental methods. In this appendix, we describe the details of the WSC analysis conducted for this evaluation. Typically, a WSC will compare the estimate from an RCT with that from a non-experimental (NE) method; the closer the estimate, the better is the NE design. As discussed in the main body of the report, under certain conditions, it is numerically equivalent to assess the difference between the control and comparison groups. Thus, we focus on comparisons of the low-cost connections control group and various subsets of the WSC comparison group.[98]

Our approach is to start with a simple comparison of mean outcomes between the control group and the WSC comparison group without using any NE method (the unadjusted model). We expected that this unadjusted model would result in non-zero differences suggesting bias for this model. The WSC analysis was designed to capture the benefits of using seven combinations of our three design elements—controlling for a pretest (P), using a local comparison group (L), and matching based on a rich set of additional covariates (C)—to investigate to what extent they reduce or eliminate the bias of the simple unadjusted comparison. Starting with the unadjusted model ("None"), which is the base combination, we describe in Table G.1 the eight combinations of elements we analyzed.

Table G.1. Design element combinations analyzed

Combination	Local comparison group	Pretest	Rich set of covariates
None			
L	L		
P		P	
C			C
LP	L	P	
LC	L		C
PC		P	C
LPC	L	P	C

We estimated bias by using the coefficient estimate on a control group indicator in a regression with all observations from the control group and the relevant observations from the WSC comparison group. The relevant observations varied across models depending on the combination of design elements under consideration. In the models with no design elements and the one with only the pretest, we used all observations from the WSC comparison group. The regressors also varied depending on the model. In the models with the pretest design element, we controlled for the baseline value of the outcome variable. In the models with rich covariates, we controlled for the linear propensity score as a covariate (in addition to selecting the sample based on the propensity score).

[98] The WSC comparison group was formed from the T&D comparison communities such that the number of households in communities with access to new lines was approximately the same. More specifically, we selected all communities with access to new lines and randomly selected communities without new lines up to the point where the proportion of households in communities with new lines in the WSC comparison group just exceeded the proportion in the control group.

The pretest design element requires the addition of the baseline value of the outcome as a control variable in the regression used to estimate bias. To be able to implement this design element for all models, we limited our analyses to variables with pretest values collected at baseline.

The local comparison group design element implies targeting of comparison communities that are located within 40 kilometers (km) of the control communities. As explained below, we did not impose the distance limit for control communities that lacked any nearby comparison community meeting this requirement.

The rich covariates design element means the use of the nearest neighbor matching based on propensity scores at the household level to limit the sample of comparison households to those with propensity scores most similar to the households in the control group.

In the first part of the appendix, we present information on the outcome variables that we selected. In the second part of the appendix, we describe our process for implementing the local comparison group design element (L), the rich covariates design element, and both elements together (LC). In the third part of the appendix we present two robustness checks—the first presents results by outcome domain while the second uses comparison communities drawn only from the non-electrified comparison group communities. The final sections of the appendix contain the list of potential propensity score matching variables considered and notes on data-cleaning.

A. Outcomes

We included all 59 variables in the outcome analysis that were primary or secondary outcomes analyzed as part of the RCT and that had a baseline pretest measurement. In Table G.2, we present the list of outcome variables analyzed together with information on the domain they covered, whether they were primary or secondary outcome variables, and whether we used a log transformation of the variable, as described below.

Table G.2. Outcomes used in within-study comparison

Outcome	Domain	Primary or secondary	Log
Electricity produced from any source monthly (kWh)	Energy use	Primary	X
Liquid fuel purchased monthly (L)	Energy use	Primary	X
Used electricity from any source other than batteries	Energy use	Secondary	
Hours of monthly use of electric tools and appliances	Energy use	Secondary	X
Electricity from grid monthly (kWh)	Energy use	Secondary	X
Light consumed monthly (lumen-hours)	Energy use	Secondary	X
Monthly cost of light (TZS)	Energy use	Secondary	X
Owns at least one mobile phone	Energy use	Secondary	
Number of electric tools and appliances owned	Energy use	Secondary	X
Nongrid electricity (kWh)	Energy use	Secondary	X
Monthly mobile phone recharge cost (TZS)	Energy use	Secondary	X
Solid fuel (kg) obtained monthly	Energy use	Secondary	X

Outcome	Domain	Primary or secondary	Log
Hours per day			
Children age 5 to 14 studying at night	Education and child TU	Primary	
Children age 5 to 14 studying, total	Education and child TU	Primary	
Youth age 15 to 24 studying at night	Education and child TU	Secondary	
Youth age 15 to 24 studying, total	Education and child TU	Secondary	
Collecting water and fuel—child	Education and child TU	Secondary	
Leisure/entertainment—Child	Education and child TU	Secondary	
Sleeping at night—Child	Education and child TU	Secondary	
Performing other household chores—child	Education and child TU	Secondary	
Percent of children age 5 to 14 attending school	Education and child TU	Secondary	
Any child age 5 to 14 attending electrified school	Education and child TU	Secondary	
CO2 per month (kg)	Health and safety	Secondary	X
Any youth age 15 to 24 in household missed work in the last 30 days due to illness	Health and safety	Secondary	
HIV information from television/radio/internet/telephone in last 30 days	Health and safety	Secondary	
Soot per month (gBC)	Health and safety	Secondary	X
At least one IGA	Business and adult TU	Primary	
Any IGA that uses grid electricity	Business and adult TU	Secondary	
Monthly revenue from IGAs	Business and adult TU	Secondary	X
Annual revenue from IGAs	Business and adult TU	Secondary	X
At least one member is a paid employee	Business and adult TU	Secondary	
Hours per day			
Performing household chores and child care—female	Business and adult TU	Secondary	
Performing household chores and child care—male	Business and adult TU	Secondary	
Collecting water and fuel—female	Business and adult TU	Secondary	
Collecting water and fuel—male	Business and adult TU	Secondary	
Cooking, processing, and preparing food—female	Business and adult TU	Secondary	
Cooking, processing, and preparing food—male	Business and adult TU	Secondary	
Sleeping at night—female	Business and adult TU	Secondary	
Sleeping at night—male	Business and adult TU	Secondary	
Other IGAs—female	Business and adult TU	Secondary	
Other IGAs—Male	Business and adult TU	Secondary	
Reading and studying—female	Business and adult TU	Secondary	
Reading and studying—male	Business and adult TU	Secondary	
Socializing and resting—female	Business and adult TU	Secondary	
Socializing and resting—male	Business and adult TU	Secondary	
Wage labor (agriculture and nonagriculture)— female	Business and adult TU	Secondary	
Wage labor (agriculture and nonagriculture)—male	Business and adult TU	Secondary	
Nonwage labor (other productive activities)—female	Business and adult TU	Secondary	
Nonwage labor (other productive activities)—male	Business and adult TU	Secondary	
Nonelectricity consumption (TZS) in last year	Economic well-being	Primary	X
Per capita daily consumption (TZS)	Economic well-being	Secondary	X
Flush toilet	Economic well-being	Secondary	
Electrifiable based on wall and roof material	Economic well-being	Secondary	
Per capita daily income (TZS)	Economic well-being	Secondary	X
Indoor piped water during rainy and dry seasons	Economic well-being	Secondary	

Table G.2. (*continued*)

Outcome	Domain	Primary or secondary	Log
Consumes less than $1 per day, per person	Economic well-being	Secondary	
Consumes less than $2 per day, per person	Economic well-being	Secondary	
Number of rooms for sleeping	Economic well-being	Secondary	
Total assets (TZS)	Economic well-being	Secondary	

Note: gBC=grams black carbon, kg=Kilograms, kWh=Kilowatt hours, IGA=Income-generating activity, L=Liters, TZS=Tanzanian shillings, TU = time use.

For variables with distributions that are very skewed and thus better approximated by a log-normal distribution rather than a normal distribution, we use the logarithm of the variable. If some households have zero outcomes, we constructed the dependent variable as log(1+outcome variable). To analyze outcomes on a scale that could be compared across variables, we standardized by dividing by the standard deviation of the follow-up outcome in the full set of 151 control communities.

B. Design elements and comparison group composition

The design elements take different approaches to addressing bias in a simple comparison. The first design element controls for a pretest (P) but does not otherwise change the composition of the comparison group. The local comparison group (L) and matching based on a rich set of additional covariate (C) elements attempt to address bias by selecting a subset of potential comparison households that are most comparable to the control households. In Table G.3, we provide a brief overview of the composition of the WSC comparison group for the different combinations of design elements.

In the following subsections, we provide a detailed description of the comparison groups selected when selecting a local comparison group; the propensity score matching based on a rich set of covariates; and the combination of local comparison group and rich covariates.

Table G.3. Composition of comparison group by design element

Combination	Comparison group composition
None, P	All households in WSC comparison communities
L, LP	One randomly chosen household per control household, selected from the households in the up to four closest local WSC comparison communities
C, PC	One comparison household per control household, selected through nearest- neighbor matching from among all WSC comparison households. Selection based on propensity score estimated by using rich set of covariates
LC,LPC	One comparison household per control household, selected through nearest- neighbor matching from the households in the up to four closest local WSC comparison communities. Selection based on propensity score estimated by using rich set of covariates

1. Local comparison group

Using GIS data on household location, we computed the centroid for the surveyed households in each community. We then calculated bilateral distances between the centroids of all control and comparison communities. In Table G.4, we provide information on the average, minimum, and maximum distance of the four communities that are closest to each control community, including the control communities that had less than four comparison communities within 40 kilometers.

Table G.4. Distances between control and comparison communities

Distance to four nearest comparison communities from each control community in km				
	Nearest	2nd nearest	3rd nearest	4th nearest
Average	19.9	31.6	40.4	56.3
Minimum	0.4	1.1	1.5	2.3
Maximum	72.0	120.0	162.4	162.6
SD	17.0	26.4	29.3	29.9

Note: This table covers 76 comparison communities and 151 control communities.

We then define the local comparison communities to be restricted to the communities within a radius of 40 kilometers.[99] In Table G.5, we present information on the number of control communities in our data by how many comparison communities were located within 40 kilometers.

Table G.5. Control communities by number of comparison communities within 30 kilometers

Comparison communities within 40 kilometers	Control communities
0	18
1	30
2	19
3	36
> = 4	**48**
4	6
5	10
6	4
7	2
8	1
9	2
10	15
11	4
12	1
13	3
15	18

Note: This table covers 76 comparison communities and 151 control communities.

[99] In choosing the radius for the local comparison group, there is a trade-off between being more local and the number of potential comparison group observations that can be selected. We initially concluded that 30 km would be a reasonable radius based on the following criteria: that 30 kilometers is an upper bound for the distance most adults would reasonably walk in a day and used it as one measure of how much two communities would be subject to similar influences. The data also show that 30 kilometers is approximately the average distance to the district capital. However, the number of potential control group observations for a large number of villages was zero or very small. We thus widened the radius to a 40 km radius.

For each control community, we created the locally matched comparison group by selecting households from the four closest comparison communities that were located within 40 kilometers of the control community. In instances of fewer than four such communities but at least one, we used the households in all communities within the 40-kilometer radius. We performed one-to-one matching for each control group household by randomly selecting one comparison group household without regard to other characteristics of control or comparison households.[100] We did not replace respondents when selecting comparison households for a control community because, with the random selection of households within communities, selection with replacement would increase variance and not decrease bias. However, when we exhausted the pool of local comparison observations for a given control community—for example, in cases of only one comparison community to draw from and with few households—then we did replace all observations.[101]

No comparison community was within 40 kilometers of 18 control communities. The average distance to the closest comparison community for the 18 control communities was 55.7 kilometers relative to 19.9 kilometers for the sample as a whole. The 744 households in the 18 communities represent about 18.8 percent of our analysis sample of 3,951 observations. To select comparison households for the 744 households, we selected one household at random from all comparison communities, without replacement and without regard to distance.[102]

2. Matching on rich set of covariates

We selected a rich set of covariates by using a hybrid between an initial theory-based selection of variables and iterative variable selection that is illustrated in Figure G.1 below and is similar to one used by Heckman, Ichimura, Smith and Todd (1998). This process was implemented without looking at the follow-up outcome data so selection of the covariates was not influenced by knowledge of what the bias estimates would be. The final list of variables selected is given in Table G.6. The list of variables considered but not included in the final model is given in section E below.

The main theoretical driver for choosing variables to consider for the propensity score model was that communities were selected for new lines based on the expected costs and benefits. Costs were approximated by distance to existing lines and benefits by expected number of customers. We did not have data on those variables. As a proxy for distance to the nearest line we used distance to the nearest regional or district capitals (which were prioritized for getting connected earlier). As a proxy for expected customers we used the log of the number of households in the community. As can be seen in Table G.6 both of these variables ended up in our final model. We also considered a rich set of additional covariates designed to cover the types of factors that might also be expected to be associated with costs and benefits of building new lines into a community. These included (1) distances to locations with important services, such as hospitals,

[100] This was because, here, we want to isolate the contribution of local comparison groups from matching on covariates. The combination of the two is described in F.B.4.

[101] We capped the number of times a comparison group household could be selected in this way to 9, to be consistent with the propensity score matching procedure described below.

[102] It was thus possible for households in the comparison group to exceed the cap of being selected 9 times if they were also selected in this unrestricted selection.

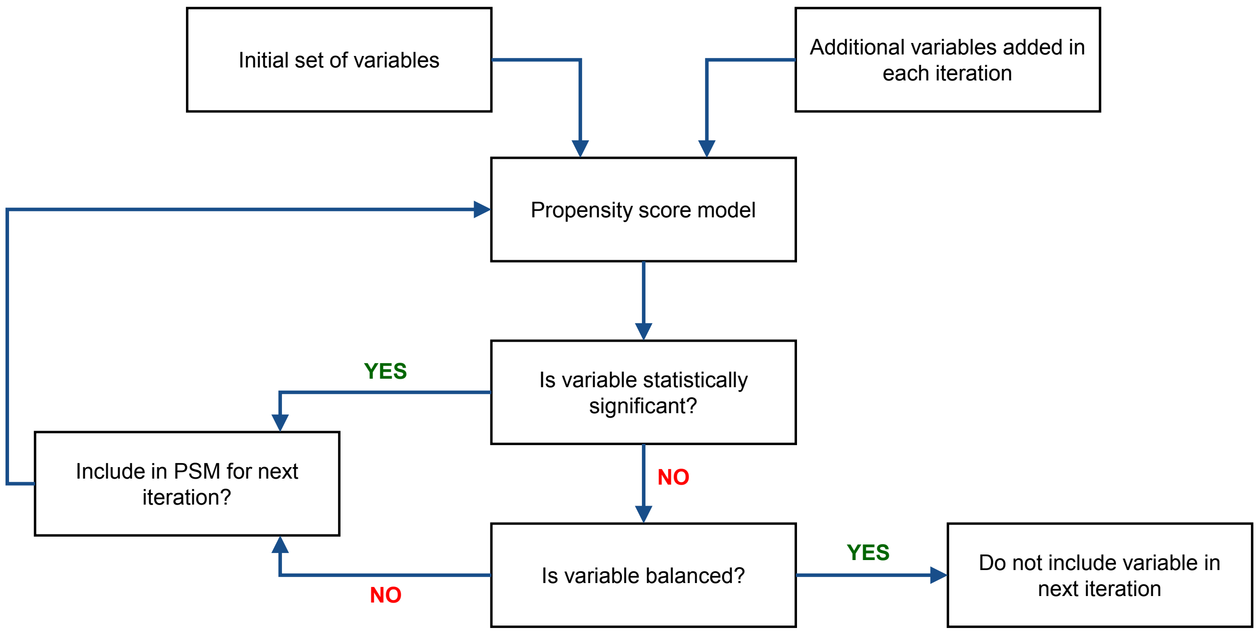
secondary schools, health facilities, that might result in a higher likelihood of being connected; (2) other characteristics of the communities such as whether they had a paved road, the percentage of households connected at baseline, and information on the local economy; (3) demographic characteristics of households, such as level of education and whether the head is male; and (4) a number of functions of the distance and population variables. We note that the potential set of rich covariates is larger as there is pretest information on all outcome variables considered in this analysis. We did not include those variables in the set of potential matching covariates so that we could separately assess the usefulness of the pretest.

In each iteration we checked each covariate in the current model to see if it was (1) statistically significant in the propensity score logistic regression with controls for the other covariates, and (2) if it differed in a statistically significant way between the control and matched comparison groups in that iteration. If either was the case then the next iteration of the propensity score model included this covariate, as shown in the bottom left box of Figure G.1. We started with the full WSC comparison group and a set of covariates that we thought were most likely to be associated with factors that affected the selection of communities into the line extensions intervention group, represented by the box in the top left of Figure G.1. We then estimated the coefficient estimates on these covariates in the logistic regressions described above, allowing for clustering by community. We then selected an initial set of PSM comparison group households that matched the control group based on the resulting propensity scores and then checked for balance by running a regression for each of these variables on an indicator for being in the control group rather than the comparison group using this new PSM comparison group in place of the full WSC comparison group.[103] If a covariate was statistically significant in the propensity score regression or unbalanced between the control and comparison groups, we kept it in the next iteration of the propensity score model. In subsequent iterations of the model we dropped statistically insignificant covariates and added additional sets of community and household-level covariates (represented by the box on the top right of Figure G.1) until all covariates had been considered and none of those omitted were found to be statistically significant in either regression based on the final PSM comparison group. Also no omitted variables were statistically significant in the logistic regressions without other covariates based on the final PSM comparison group.[104]

[103] We implemented nearest-neighbor matching with limited replacement, where the number of times a comparison household could be matched was capped at 9 times.

[104] None of the propensity score matching algorithms in Stata currently have the capability to provide balance tests when observations are clustered, so we could not rely on an already written program.

Figure G.1. Covariate selection for propensity score model



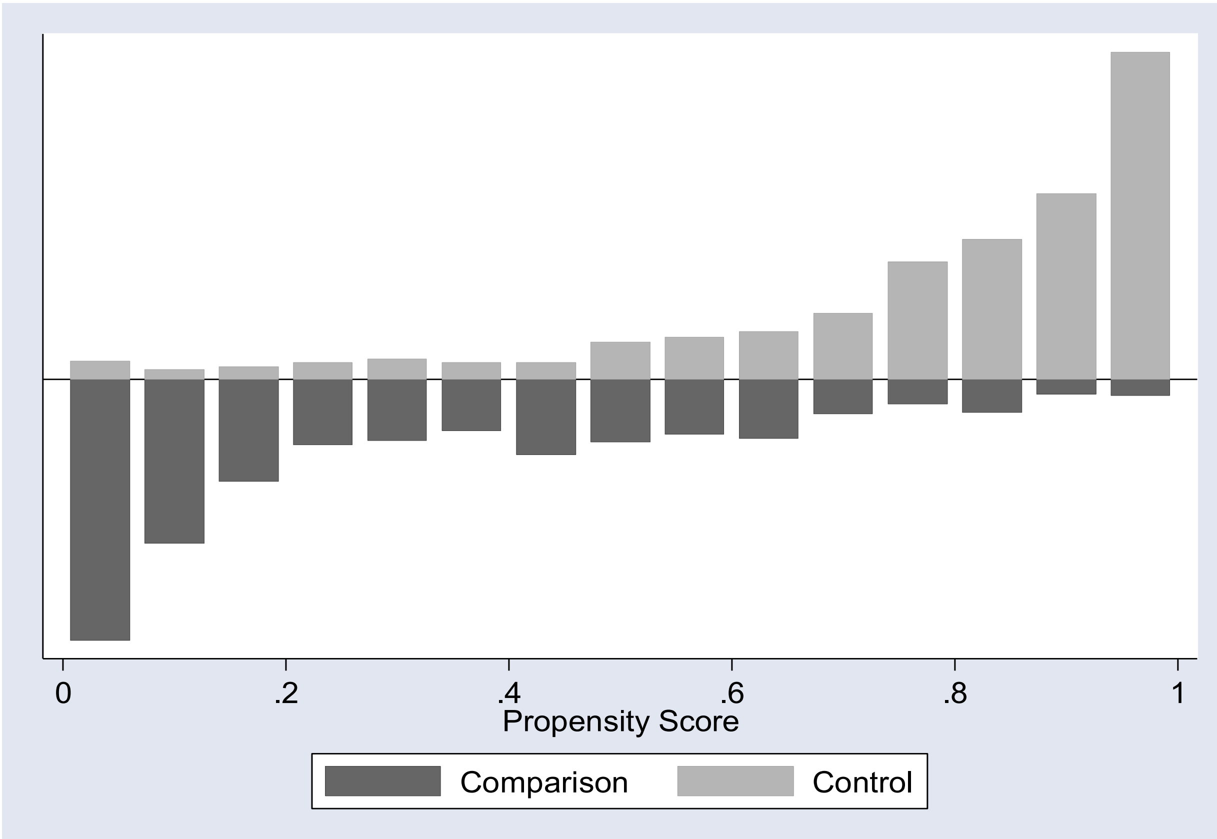
3. The final propensity score

The rich covariates design element used a final propensity score based on the variables selected through the process described. We used nearest-neighbor matching with replacement at the household level. Thus, each comparison household could appear multiple times, though we capped the number of times a household could appear at 9.[105]

In Figure G.2, we show the overlap between the unweighted control and comparison groups in the propensity score and document the overlap in the propensity scores between the control and comparison groups for all levels of the propensity score. All control observations were on the area of common support. In Table G.6, we show the final propensity score model.

[105] This was the 90th percentile for the number of times a household was matched in the unrestricted case.

Figure G.2. Overlap in propensity scores for unmatched samples



Note: Based on data from all 76 WSC comparison communities with 2,919 households and 151 control communities with 3,951 households.

Table G.6. Final Propensity Score Model – Odds Ratio

Variable	Coefficient (standard error)
Community classified as village at baseline	6.431*** (3.521)
Distance to nearest primary school at baseline	3.612*** (1.370)
Nonzero Distance to nearest secondary school at baseline	2.874** (1.223)
Distance to nearest secondary school at baseline, mean impute if miss	1.163** (0.082)
Zero Distance to nearest health facility at baseline	0.239** (0.150)
Log Distance to nearest health facility at baseline	0.194** (0.124)
Community has weekly market at baseline	6.105*** (3.226)
Community accessible by paved road at baseline	0.930 (0.415)
Percentage of households connected to the main grid	119.667*** (221.309)
Community has land line phones	0.322* (0.195)
Community was connected to main grid between 1940 and 1975	0.094** (0.107)
Community was connected to main grid between 1976 and 1990	0.036*** (0.029)
Community was connected to main grid between 1991 and 2001	0.178*** (0.108)
Main source of community income is Trading	0.127** (0.116)
Village has access to new lines	2.137 (1.278)
Child health problems - if child	0.711 (0.148)
Completed Secondary Education - Key Female	1.106 (0.243)
Completed Any Education - Key Female	0.708** (0.095)
Completed Secondary Education - Key Male	0.729 (0.206)
Completed Tertiary Education - Key Male	2.952 (2.036)
Number of rooms household has for sleeping, baseline	1.067* (0.038)
Log Number of community members	1.952** (0.560)

Table G.6. *(continued)*

Variable	Coefficient (standard error)
Key Male Married	0.605** (0.126)
Value of home (0 if none) (TZS), baseline	1.000** (0.000)
Minimum distance to regional/district capital is between 27 and 55 kilometers	2.614** (1.184)
Log number of businesses at baseline	0.501** (0.168)
Constant	0.202 (0.375)
Observations	6,870

Notes: Table presents the final propensity score model for the WSC. The percent correctly classified as being in the treatment (control) group based on whether the probability was >= (<) 0.5 was 82.29 percent. The pseudo R-squared was 0.405.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In Table G.7, we show the mean and variance of the propensity scores for the unmatched and matched samples. We can see that the propensity scores of the control and unmatched comparison groups as a whole are unbalanced. However, as expected, the one-to-one nearest-neighbor matching leads to two groups that show only a small difference with respect to the average propensity score.

Table G.7. Propensity scores for unmatched and matched samples using final propensity scores based on rich covariates

Design element	Statistic	Comparison	Intervention	Difference (s.e.)
Entire WSC comparison sample (None, P)	Mean	0.301	0.777	0.476 (0.0244) ***
	Variance	0.07	0.051	
	N	2,919	3,951	
Matched based on rich covariates (C,CP)	Mean	0.717	0.777	0.061 (0.034)*
	Variance	0.04	0.051	
	N	922 unique 3,951 weighted	3,951	

Notes: Average estimated propensity score for the control and comparison households, based on the propensity score model in Table G.6. For the unmatched case, the mean is based on all observations in the comparison and control groups. For the matched case, for the comparison group, it is the weighted mean, using the propensity score weights whereby the weight equals the number of control group observations to which each comparison group observation is matched, subject to the cap mentioned in the text. For the control group, the unmatched and matched means are the same; because there is common support for the propensity scores for control households, no control households were dropped from the analysis.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

"s.e." = standard error.

In Table G.8, we present the balance tests for the variables included in the final propensity score model. The difference between control and comparison groups was not statistically significant at the 5 percent level for any of the variables included in the propensity score model, suggesting that the comparison group constructed by nearest-neighbor matching was well balanced. In addition, we conducted tests for balance between control and comparison groups for all of the other variables that were not part of the final propensity score model. Out of 61 variables, none were statistically significant at the 5 percent level and 6 at the 10 percent level after matching. The list of variables not included in the model appears in section E of this appendix. Variables statistically significantly different between the control and comparison groups appear in the notes to Table G.8.

Table G.8. Balance tests for variables in final propensity score model

Variable	Difference in means	Standard error of difference
Community classified as village at baseline	-0.012	0.909
Distance to nearest primary school at baseline	-0.121	0.590
Nonzero Distance to nearest secondary school at baseline	0.158	0.192
Distance to nearest secondary school at baseline, mean impute if miss	0.588	0.234
Zero Distance to nearest health facility at baseline	0.111	0.365
Log Distance to nearest health facility at baseline	-0.050	0.577
Community has weekly market at baseline	0.175	0.096
Community accessible by paved road at baseline	-0.091	0.326
Percentage of households connected to the main grid	0.004	0.825
Community has land line phones	0.003	0.950
Community was connected to main grid between 1940 and 1975	0.002	0.908
Community was connected to main grid between 1976 and 1990	-0.005	0.754
Community was connected to main grid between 1991 and 2001	-0.024	0.762
Main source of community income is Trading	0.019	0.599
Village has access to new lines	0.032	0.638
Child health problems - if child	-0.029	0.406
Completed Secondary Education - Key Female	0.002	0.880
Completed Any Education - Key Female	0.021	0.561
Completed Secondary Education - Key Male	-0.006	0.826
Completed Tertiary Education - Key Male	0.000	0.989
Number of rooms household has for sleeping, baseline	-0.109	0.320
Log Number of community members	0.405	0.051
Key Male Married	0.000	0.987
Value of home (0 if none) (TZS), baseline	342	0.748
Minimum distance to regional/district capital is between 27 and 55 kilometers	0.110	0.307
Log number of businesses at baseline	0.207	0.401

Notes: TZS=Tanzanian Shillings.

* p <0.10, ** p < 0.05, *** p < 0.01

The variables that were potential covariates for the variable selection model, but were not retained, appear at the end of this appendix. In the balance test following the final model, some variables were unbalanced between the control and comparison groups at the 10 percent level of statistical significance. These variables are: community has at least one electrified business at baseline; zero amount of kerosene used by household monthly, baseline; log amount of kerosene used by household monthly, baseline; log Number of hours electric tools and appliances used by household, monthly, baseline; landline Minutes Per Week; and landline monthly bills.

4. Combining local comparison group and rich covariates

The combination of the local comparison group and rich covariates design elements matches control households to comparison households, but only within the set of local comparison communities, as defined above. We matched approximately with replacement in that we limited the number of times any comparison household could be matched to 9, corresponding to the 90th percentile of the number of times comparison households were matched in the geographically unrestricted match. We imposed the limit because the maximum number of times one household from the comparison group was matched without the restriction in the local match was over 100, leading us to expect a potentially large variance.[106]

As in the case where we create a local comparison group, we were faced here with the situation of no comparison community within 40 kilometers to match households based on the propensity score. In this case, we allowed for unrestricted matching so that, for the control households, the match was the same as a general nonlocal propensity score match. These are the same 744 control households from 18 communities mentioned above.[107]

In Table G.9, we show the mean and variance of the propensity scores computed from the geographically unrestricted propensity score model for the local comparison group and the comparison based on local matching with a rich set of covariates. We can see that, before the matching process, the propensity scores of the control and comparison groups were highly dissimilar. As expected, the one-to-one nearest-neighbor matching within the local geographic area led to two groups that showed much smaller differences with respect to the average propensity score. The average difference in propensity scores is now reduced by 57.3 percent, though the difference is still statistically significant. The main objective of matching with local comparison group observations is to ensure that the control and comparison groups share potentially unobserved common influences. The common influences might be geographic factors, weather, local infrastructure, common markets, and so forth. Our local matches are less well balanced based on observed factors as captured in the propensity score but may be better balanced on the unobserved ones. An alternative approach would exclude from the local match those observations from the intervention groups for which the local match was too dissimilar in terms of the propensity score. Such an approach could be done as a robustness check in future research.

---

[106] Given that matching is now not always with replacement, the order in which control households are matched becomes important. We match households with the highest propensity score first.

[107] Because of this second possibility of being matched, the maximum number of times comparison households can be matched can exceed 9 times.

Table G.9. Propensity scores for local comparison group and local matching

If Matched	Statistic	Comparison	Intervention	Difference (s.e.)
Local comparison Group (L,LP)	Mean	0.344	0.777	0.433 (0.060)***
	Variance	0.074	0.051	
	N	1,857 unique 3,951 weighted	3,951	
Local matching LC,LPC)	Mean	0.592	0.777	0.185 (0.049)***
	Variance	0.054	0.051	
	N	675 unique 3,951 weighted	3,951	

Notes: Average estimated propensity score for the control and comparison households is based on a propensity score model that includes the variables listed in Table G.6. For the unmatched case, for the local comparison group, the mean is based on one locally selected observation per control household, with limited replacement. For the matched case, we constructed the comparison group by matching a control household to the closest household in the local communities, using the propensity score weights. For the control group, the unmatched and matched means are the same.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

"s.e." = standard error.

C. Bias and significance tests for differences in bias

1. Bias

We define bias in the unrestricted model ($Bias_y(None)$ as the absolute value of the difference between the control group and the WSC comparison group for an outcome *y*, standardized by the standard deviation of the outcome in the control group. Thus,

$$Bias_y(None) = abs(\beta_{\gamma,None}) / sd(y)$$

For each combination of design elements CD, we define bias for an outcome *y* as follows:

$$Bias_y(CD) = \beta_{y,CD} sign(\beta_{\gamma,None})$$

We average the biases across all 59 outcomes to compute the average bias for a design element, $\overline{Bias(CD)}$. The percentage change in bias for a combination of design elements CD is defined relative to the unrestricted model, i.e.:

$$\%\Delta Bias_y(CD) = 1 - \frac{\overline{Bias(CD)}}{\overline{Bias(None)}}$$

2. Significance tests for differences in bias

In Table G.10 we present tests for whether the difference in bias between each pair of design elements is statistically significant based on regressions in which the outcome difference for each of the 59 variables is treated as a separate observation. All differences on the diagonal are zero since they compare a design element to itself so they are left blank. The upper right portion of the table is also left blank since it would contain a mirror image of the lower left portion with all signs reversed.

The first column presents the bias reduction achieved by the combinations of design elements since it compares the bias of these models with that of the unadjusted model, and thus mirrors the results from the last column of Table VII.9 (though with *p*-values instead of standard errors). The following columns compare the bias reduction from the design elements of the respective row and column. A negative value means that the design element of the row reduces bias by more than the design element of the column, indicating better performance of the row element. The numbers in brackets are the *p*-values for statistical significance. Statistical significance is calculated controlling for fixed effects for each variable and for each design element combination, and using robust standard errors clustered at the variable level.[108] The remaining variation is caused by the design element/variable combinations which we treat as random in this analysis.

In 67 of the 70 comparisons we did (including our robustness checks), design elements reduced bias though the differences were often not statistically significant.[109] Design elements that included the rich covariates design element always reduced bias in a statistically significant way relative to not including rich covariates. Including the local design elements and pre-test also reduced bias in statistically significant ways in many cases.

---

[108] Cameron and Miller (2013) discuss the benefits of allowing residuals to be correlated differentially within clusters in models with cluster fixed effects. For example, the correlations between results for the models that use local matching might be higher than between those and the models that do not use local matching.

[109] We had 7 combinations of design elements that included at least one element. Each of these was compared to using no design element. We ran the results for all 59 variables combined and for each of 4 domains giving us 5 sets of variables. Finally, we ran our models first using the communities matched on the counterfactual (getting new lines) and separately, using only communities without new lines. In two of the three cases where bias rose it rose by only 7 percent. In one other it rose by 20 percent (education and time use domain, local comparison group, comparison communities without new lines).

Table G.10. Statistical significance of bias reduction differences across design element combinations

Combination of design elements	Difference in estimated bias reduction (Row - Column) None	L	P	C	LP	LC	PC	LPC
None								
L	-0.018 [0.028]							
P	-0.014 [0.000]	0.005 [0.604]						
C	-0.052 [0.000]	-0.034 [0.040]	-0.038 [0.003]					
LP	-0.029 [0.001]	-0.011 [0.000]	-0.015 [0.057]	0.023 [0.128]				
LC	-0.069 [0.000]	-0.051 [0.000]	-0.055 [0.000]	-0.017 [0.175]	-0.040 [0.000]			
PC	-0.054 [0.000]	-0.036 [0.022]	-0.040 [0.001]	-0.002 [0.535]	-0.025 [0.083]	0.015 [0.217]		
LPC	-0.068 [0.000]	-0.049 [0.000]	-0.054 [0.000]	-0.015 [0.215]	-0.039 [0.000]	0.001 [0.398]	-0.013 [0.257]	

Notes: Difference in estimated average bias between each pair of design elements from Table VII.9, as well as the estimated *p*-values in brackets. The *p*-values are based on cluster-robust standard errors to allow correlations between results across design element combinations to differ within variables (Cameron and Miller, 2013).

D. Robustness checks

In this section we present two additional analyses. First, we analyzed how bias is affected by the various combinations of design elements separately for four outcome domains: energy use; education and child time use; business and adult time use; and economic well-being.

Second, we used 104 communities that did not have access to electricity lines at endline as an alternative comparison group in order to study whether the methodology fails when there is a potentially very important observed characteristic that we cannot account for.

1. Results by outcome domain

In Table G.11 we present the results separately by each of four outcome domains. The 59 outcomes we use in our within-study-comparison analyses actually cover five of the domains used in the rest of this study: 1) energy use; 2) education and child time use; 3) business and adult time use; 4) economic well-being; and 5) health and safety. However, there were only four variables in the health and safety domain so we moved those to other domains for this analysis. The variables “Amount of external pollution from carbon produced per month (kg CO_2)” and “Amount of internal pollution from soot produced per month (g BC)” were moved to the energy use domain given that they are calculated based on energy use; the variables “Any adult 15-24 in household missed work in the last 30 days due to illness” and “Household received HIV info from TV/radio/internet/phone in last 30 days” were moved to the business and adult time use domain since they describe adult time use.

Column 2 of Table G.11 presents results for all 59 outcomes. These were also presented in Table VII.9. All combinations of design elements reduce bias compared to using none except in the business and adult time use domain where local matching increases bias by 7 percent (from 0.067 to 0.071). In addition, each of the four combinations of design elements usually does better than using one element at a time, with one exception—the local comparison group with a pre-test usually does not do as well as rich covariates. Similarly, when looking at results by domain, combinations usually do better than single design elements except in one domain (business and adult time use) where using rich covariates alone generally does better. Perhaps most importantly, using all three elements always reduces bias by about as much as any other combination. The largest difference in the other direction is 0.022 (business and adult time use: all three elements versus using a pre-test and rich covariates).[110]

Table G.11. Average bias by outcome domain

Combination of design elements	All 59 Outcome variables	Energy Use	Education and Child Time Use	Business and Adult Time Use	Economic Well-Being
[1]	[2]	[3]	[4]	[5]	[6]
None	0.086	0.081	0.106	0.067	0.119
L	0.067	0.073	0.044	0.071	0.072
P	0.072	0.067	0.095	0.053	0.101
C	0.033	0.044	0.085	-0.008	0.069
LP	0.057	0.060	0.039	0.059	0.064
LC	0.017	0.011	0.004	0.026	0.013
PC	0.031	0.039	0.077	-0.005	0.066
LPC	0.018	0.009	0.004	0.027	0.021

Note: Table G.11 presents results for the 59 primary and secondary outcomes considered in the RCT analysis that had a pretest measure, as well as separately by outcome domain. Column 2 presents the standardized average bias under different combinations of design elements, where the standardized bias was averaged over the 59 variables. The variables were standardized by the standard deviation of the control group outcome. "None" indicates that a simple difference was taken between control and comparison groups. "L" indicates that a local comparison group was formed; "P" that the regressions controlled for a pre-intervention measure; and "C" that the analysis involved propensity score matching based on a rich set of covariates. The text describes the eight design control features in more detail. Columns 3 through 6 present the results, respectively, for the four domains of outcome variables: energy use; education and child time use; business and adult time use; and economic well-being. Since the health domain, one of the original five domains, consisted of only four variables, they are regrouped into one of the other four domains (see main text for details).

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

s.e. = standard error.

2. Non-electrified communities as comparison group

As a second robustness check, we repeat the main analysis of the WSC with an alternative pool of comparison communities, communities without access to electricity. We set up new propensity score models, and then assessed bias in the different design combinations with this comparison group. Our first finding is that the comparison communities are sufficiently different

[110] In this case we compare the 0.027 achieved by all three design elements to the absolute value of the bias found for the combination of pre-tests and rich covariates (-0.005) since over-correcting could also be a problem in theory, though it was not in this study.

that we are not able to find a propensity score model that balances all variables considered.[111] If the purpose of the analysis were to estimate the impact of the subsidy, we would have aborted the analysis at this point. Instead, we proceed and include the unbalanced variables as covariates in the outcome regression in the spirit of a "double robust" analysis. We proceed in order to assess the limits and robustness of our main result that combinations of design elements provide a form of insurance against any of the design elements not being effective at reducing bias.

Table G.12 presents the results from the analysis with non-electrified communities. As in Table VII.9 which contains the corresponding results for our main analysis, column 2 presents the average bias across all 59 outcomes first for the unrestricted comparison ("None") and then for each of the different combinations of design elements. Column 3 presents tests of significance between the combinations of design elements and the unrestricted model. We find that the initial bias in this group of comparison communities is larger to begin with (0.120 versus 0.086), and the lowest bias (0.029) is larger than in the main analysis (0.017) which includes communities with and without access to electricity. Using all three design elements does about as well as any of the other combinations though using rich covariates alone, local matching with rich covariates, or a pre-test with rich covariates does about as well. Using local comparison groups alone, a pre-test alone or these two elements in combination does not lower bias as much with this lower quality comparison group as it did with the higher quality group. With respect to the main research question of this study, we also find that combinations of design elements are usually more effective at reducing bias than single design elements with the one exception that combining the local matching and pre-test does not do as well as rich covariates alone.

[111] These four variables are: Community classified as village at baseline; Main source of income in community at baseline is farming, fishing, livestock; Price of land in community at baseline; Population of the community is below 282 inhabitants. The percent correctly classified as being in the treatment (control) group falls from 82.29 percent in the main model (presented in Table G.6) to 71.64 percent in this alternative model limited to communities without access to electricity. The pseudo R-squared falls from 0.405 to 0.196.

Table G.12. Average bias across 59 outcome variables

Combination of design elements	Average standardized bias (s.e.)	Difference in average standardized bias to base category ("None") (s.e.)
None	0.120*** (0.013)	Base category
L	0.114*** (0.014)	-0.006 (0.009)
P	0.097*** (0.012)	-0.023*** (0.006)
C	0.033*** (0.012)	-0.087*** (0.011)
LP	0.094*** (0.012)	-0.025** (0.010)
LC	0.030** (0.013)	-0.090*** (0.014)
PC	0.029** (0.012)	-0.091*** (0.012)
LPC	0.029** (0.012)	-0.091*** (0.013)

Note: Table G.12 presents regression results using one observation for each combination of design elements with the 59 primary and secondary outcomes considered in the RCT analysis that had a pretest measure. Thus, there are a total of 472 observations. The potential group of comparison observations comes from communities without access to electricity. The middle column presents the standardized average bias under different combinations of design elements, where the standardized bias was averaged over the 59 variables. The variables were standardized by the standard deviation of the control group outcome. "None" indicates that a simple difference was taken between control and comparison groups. "L" indicates that a local comparison group was formed; "P" that the regressions controlled for a pre-intervention measure; and "C" that the analysis involved propensity score matching based on a rich set of covariates.

The text describes the eight design control features in more detail. The last column shows the differences (and standard error of the differences) between the average bias in the unadjusted comparisons and the bias when design elements were included and including variable fixed effects for each of the 59 variables. We use cluster-robust standard errors to allow correlations between results across design element combinations to differ within variables (Cameron and Miller, 2013).

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

s.e. = standard error.

Table G13 presents the results separately by outcome domain. The results are generally similar with a few exceptions. Perhaps the most noticeable is that in the education and child time use domain, using a local comparison group alone increases bias compared to the unadjusted results by 20 percent. In that same domain, using a local comparison group with a pre-test also increases bias, though by only 7 percent. All other combinations of design elements and domains show reduced bias compared to the unadjusted results. We also find that combining all three elements reduces bias by about as much as any of the other combinations. Again, the largest difference in the other direction is only about 0.02 (using a pre-test with rich covariates does better than all three design elements combined, in this case in the education and child time use domain). Finally, we once again find that using any combination of design elements does better than using one design element at a time in all cases except that using a local comparison group with a pre-test does not do as well as rich covariates. Thus, in general our results support the use of more design elements to help reduce bias.

Table G.13. Average bias by outcome domain

Combination of design elements	All 59 Outcome variables	Energy Use	Education and Child Time Use	Business and Adult Time Use	Economic Well-Being
[1]	[2]	[3]	[4]	[5]	[6]
None	0.120	0.141	0.113	0.085	0.182
L	0.114	0.139	0.135	0.079	0.145
P	0.097	0.117	0.103	0.072	0.124
C	0.033	0.043	0.065	0.006	0.051
LP	0.094	0.120	0.121	0.068	0.096
LC	0.030	0.035	0.090	0.004	0.026
PC	0.029	0.041	0.063	0.006	0.036
LPC	0.029	0.042	0.083	0.005	0.017

Note: Table G.13 presents regression results for the 59 primary and secondary outcomes considered in the RCT analysis that had a pretest measure, as well as separately by outcome domain. The potential group of comparison observations comes from communities without access to electricity. Column 2 presents the standardized average bias under different combinations of design elements, where the standardized bias was averaged over the 59 variables. The variables were standardized by the standard deviation of the control group outcome. "None" indicates that a simple difference was taken between control and comparison groups. "L" indicates that a local comparison group was formed; "P" that the regressions controlled for a pre-intervention measure; and "C" that the analysis involved propensity score matching based on a rich set of covariates. The text describes the eight design control features in more detail. Columns 3 through 6 present the results, respectively, for the four domains of outcome variables: energy use; education and child time use; business and adult time use; and economic well-being. Since the health domain, one of the original five domains, consisted of only four variables, they are regrouped into one of the other four domains. See text for details.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

s.e. = standard error.

In conclusion, we use this alternative comparison group to illustrate the degree to which our conclusions are robust when the pool from which comparison observations are selected is of lower quality. We find that there is a larger bias to start with, a smaller percentage wise reduction when looking at all 59 variables, and the pattern of bias reduction is somewhat less robust across domains, with at least one case of a fairly substantial increase in bias. Generally speaking, though, the conclusion is not very different, in that the combination of three design elements generally does about as well as or better than using only one or two design elements.

E. List of variables not in the propensity score model for the main analysis

Following is a list of the 61 baseline variables the variable selection did not select for the propensity score model:

Community has access to grid; community has at least one household within 30 meters of an existing line listing; percent of households in community connected listing; distance to nearest health service; community dispensary hours; most people get piped water in community; community has a police station; community has at least one electrified business; community has electrified tea/coffee shop, guest house, or hotel; main source of income in community is farming, fishing, livestock, etc.; price of land in community; natural log of the price of land in the community; most people in community have mobile phones; community has a sub-village; community has police station, post office, or bank; community connected to national or isolated grid; distance to population ratio is between 0 and 5 (inclusive); distance to population ratio is between 5 and 10 (inclusive); distance to population ratio is between 10 and 22 (inclusive); distance to population ratio is between 22 and 75 (inclusive); distance to population ratio is between 75 and 100 (inclusive); distance to population ratio is between 100 and 5000 (inclusive); community was never connected to main grid; community was connected to main grid between 2001 and 2011; main source of community income is farming, livestock, fishing/hunting; main source of community income is services; main source of community income is other; minimum distance to regional/district capital is between 0 and 7 kilometers (7 inclusive); minimum distance to regional/district capital is between 7 and 27 kilometers (27 inclusive); minimum distance to regional/district capital is between 55 and 158 kilometers (55 inclusive); community size is between 0 and 282 households; community size is between 283 and 493 households; community size is between 494 and 868 households; community size is above 868 households; zero amount of kerosene used by household monthly; zero Number of hours electric tools and appliances used by household, monthly; zero amount of non-electric energy produced from liquid fuel monthly; zero amount of solid fuel (kg) used by household monthly; log amount of kerosene used by household monthly; log Number of hours electric tools and appliances used by household, monthly; log amount of non-electric energy produced from liquid fuel monthly; log amount of solid fuel (kg) used by household monthly; log amount of energy produced from electricity, solid fuel, and liquid fuel; highest grade completed - key female; key female age; key female married; completed primary education - key female; completed tertiary education - key female; highest grade completed - key male; key male age; completed primary education - key male; completed any education - key male; landline calls per week; landline connection cost; landline minutes per week; landline monthly bills; child died - born alive in last 2 years; head of household is female; household has a key female; household has a key male; number of household members.

F. Data-cleaning

Baseline covariate data for rich covariates model

The variables measuring the average number of businesses connected and the distance to the nearest dispensary were missing for two communities. These observations were imputed using predictions from a regression of these variables on other community variables for all other communities in the line extensions sample. Missing household level data for covariates used in the propensity score was imputed using the mean of that covariate for the entire line extensions sample. We did not include indicators for whether values were imputed into the propensity score model as imputations were rare.

Outcome data

Baseline and follow-up outcome variables that had skewed distributions were topcoded at the 99th percentile. Then for all variables with no zero values the logarithm of that variable was formed. For variables with any zero values the transformed variable was created as log (1+variable).

This page has been left blank for double-sided copying.

APPENDIX H

EXPLORATORY ANALYSES

This page has been left blank for double-sided copying.

In Chapter VII, we estimated impacts of connecting to the grid using propensity score matching methods and a regression-adjustment approach similar to what we used to estimate impacts of the T&D lines and the FS initiative. This allowed us to account for any differences in observed characteristics between the connected and unconnected groups of households. In this appendix we describe a series of instrumental variables (IV) models we used to test the sensitivity of the findings. We focus this appendix on the IV models based on FS status and follow-up distance from the line. In addition, we briefly describe IV results based on the baseline distance. We focus on the follow-up distance rather than the baseline distance due to the problems with the baseline distance described in Appendix E.

Results based on the IV models estimate impacts for the subset of the sample that connects due to factors associated with the IVs. Those results do not generalize to households that would, or would not connect regardless of the values of the IVs. In contrast results based on our main models do generalize to such households, at least in theory. For this reason the estimated impacts based on the IV models may differ from the estimated impacts based on our main models. This, in turn, could offset any bias from results based on our main models. However, it is not clear why this would happen in practice. As such, the IV models still provide evidence regarding the possibility of bias in our main models as long as the difference in estimands does not offset the bias.

In Chapter VII, we estimated impacts of connecting to electric grid on household outcomes by using the following regression model:

(M0) $$Y_{hct} = \alpha + \beta_0 C_h + \mathrm{X}_{hc,\,t-1}\gamma + S_{(c,\,t-1)}\delta + \varepsilon_{hct}$$

where, Y_{hct} is the outcome of interest for household *h* in community *c* at time *t* (with *t* denoting the follow-up, *t-1* denoting baseline); C_h is a binary indicator of the connection status of household *h* (equals one for connected households and zero for matched unconnected households) and β_0 represents the estimated impact of connecting to the electric grid; and $\mathrm{X}_{hc,\,t-1}$ and $S_{c,\,t-1}$ are vectors of baseline household and community characteristics (listed in Table IV.7). The ***X*** vector includes the baseline outcome when available.

We estimated equation M0 by using the same approach applied for estimating equations (1) and (3) in Chapter IV: ordinary least squares regression for continuous outcome measures and logistic regressions for binary outcomes. We use the matching weights for all household-level observations included in equation M0 that were used to construct the comparison group of not connected households matched to the group of connected households as described in Appendix A. The standard errors of estimated impacts account for clustering at the community level (that is, subvillage or *mtaa*). We also estimated impacts of connecting on different subgroups by using a similar estimation approach with interactions of the connection status indicator with indicators for the subgroups of interest.

A. Sensitivity checks for impacts of connecting

Given the available data, the propensity score matching method using the benchmark model M0 is our preferred approach for estimating the impacts of connection. However, it is still possible that the impacts are biased if differences remain between connected and nonconnected households based on unobserved characteristics. To examine the sensitivity of the estimated impacts of connection to the grid based on the benchmark model M0, we estimate impacts of connection under a series of alternative models, including several using IV methods. The first two alternative models (M1 and M2) are not based on IV methods but are estimated to facilitate comparisons with the results based on IV models. The later models (M3 through M7) are all estimated by using IV and are expected to produce estimates similar to the non-IV models (M0 to M2) as long as the estimands are similar. Thus, assuming similar estimands, we can compare the estimated impacts obtained from the IV models with those from the non-IV models. We perform the Hausman test for different pair-wise comparisons. Failure to reject the null hypothesis that the parameters representing the estimated impact of connection are the same across models is interpreted as evidence of a lack of systematic bias in the estimated impacts of connection by using the matching approach in M0, though as noted above it is possible that bias is offset by the fact that the IV results cover only a subset of the population covered by the non-IV results. Thus, we are effectively assuming that the difference in estimands does not offset the bias.

The Hausman test is designed to test for the differences between two estimators of the same parameter when one estimator is known to be more efficient than the other. In our case, we compare our IV estimates to our matched comparison group estimates. In the case of only one parameter, the square root of the statistic is like a t-statistic and equals the difference between the IV and matched comparison group parameter estimates divided by the square root of the difference in their squared standard errors. The test is sometimes also known as the Durbin-Wu-Hausman (DWH) test (Nakamura and Nakamura 1981).

Model M1: T&D status control. In the first alternative model, we include an indicator for T&D status—equal to one if a household resides in a community targeted to receive new lines under the T&D activity and zero otherwise—as an additional control variable. Although connected households may be located in either the T&D communities or other communities, location in the T&D communities (intervention) affects many of the household outcomes we examine in this analysis (Chapter V). A major advantage of including the T&D indicator is that it allows us to add the FS indicator as an IV in later models. We set the FS indicator to zero for the T&D comparison group. The variation in this FS indicator gives us an identification of the impact of connection as a function solely of the random variation of the FS indicator within the intervention group and not of the nonrandom variation of that indicator between the FS treatment group and the T&D comparison group. We see little difference in the estimated impacts of connection between models M0 and M1, suggesting that the variation in connection rates between the T&D and non-T&D communities did not drive the estimated impacts of connection to the grid.

Model M2: T&D status and distance control. The probability of connection is also likely to be correlated with households' distance from the electric pole, especially among households living more than 30 meters away from an electric pole; TANESCO imposed a rule that made it generally far more expensive for households to connect if they lived outside the 30-meter range. In fact, the correlation between household- reported distance from the nearest electric pole and being connected was 0.94 among all households in the exploratory analysis.[112] In this model, we include distance from the electric pole in addition to the control variables in model M1. Even though distance from the electric pole may not be related to the outcome Y_{hct} other than through its effect on being connected, we include the distance variable at this stage to facilitate the use of an indicator of location of 30 meters from a pole as an IV in models M5 and M6. However, it is possible that unobserved household characteristics affecting the outcomes can also affect distance to an electric pole. For example, if new poles are built because a given household or a set of households wanted to be connected to the grid, then these households will be both connected and close to an electric pole. Thus, the impact of connection to the grid could be dampened when distance is included as a control. We can directly check the impact of distance as a control by comparing the impact estimates from M2 with those from M1 and M0.

Models M3 and M4: FS IV. To address the possible endogeneity in the connected variable, C_h, we estimate the impact of connection by using the IV approach. We implement this approach using a two-stage process to estimate the causal impact of connection to the grid. In the first stage, we estimate the probability of connection by using equation M3.a below:

$$\text{(M3.a)} \qquad C_h = \alpha + Z_{hc}\pi + \beta_1 I_c + \beta_2 D_h + X_{hc,t-1}\gamma + S_{c,t-1}\delta + v_{hct}$$

where C_h is a binary indicator of the connection status of household *h* and $X_{hc,(t-1)}$ and $S_{c,(t-1)}$ are vectors of baseline household and community characteristics as described above for model M0. The indicators I_c and D_h represent, respectively, the T&D status of community *c* where household *h* resides and the distance of household *h* from the nearest electric pole as in model M2. Z_{hc} is a vector of IVs. We use the predicted probability of connection status $\hat{C}_h$ from equation M3.a to estimate the impact of connecting by using the second-stage equation M3 below:

$$\text{(M3)} \qquad Y_{hct} = \alpha + \beta_0^{IV}\hat{C}_h + \beta_1 I_c + \beta_2 D_h + X_{hc,t-1}\gamma + S_{c,t-1}\delta + \varepsilon_{hct}$$

To estimate model M3 we use two-stage least squares with an indicator for the randomly assigned FS treatment status (equals one if household was located in a community assigned to receive low-cost connections and zero if not) as an instrument (Z_{hc}) for connection to the grid, as shown in equation M3.a. Under the IV approach, the estimated coefficient $\hat{\beta}_0^{IV}$ is consistent if the two following conventional IV assumptions are satisfied (conditional on the controls in our models);

[112] The correlation was 0.927 for the households that did not move from their baseline locations. Out of 8,817 households in the exploratory analysis, 1,367 households moved since the 2011 baseline survey to either a different community or within the same community.

(A1) $$E\left(Z_{hc}\varepsilon_{hct}\right)=0$$

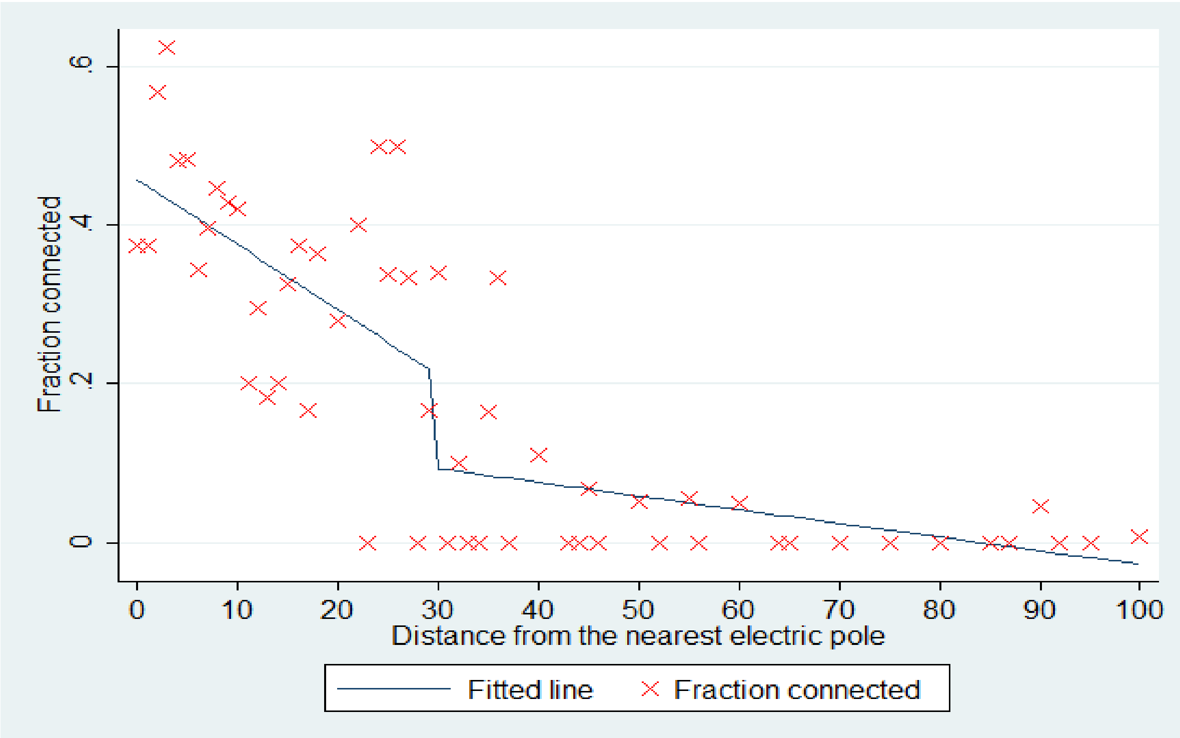
(A2) $$E\left(Z_{hc}C_{h}\right)\neq 0$$

where A1 states that the instruments are not related to the outcomes of interest Y_{hct}, except through their effect on the probability of connection, C_h, and A2 states that the instruments are highly correlated with the probability of connection, C_h, again, conditional on the controls in the models. As noted above we are also assuming similar estimands across all models discussed in this appendix—that is, the average treatment effect on the treated estimated by models 0, 1, and 2 is similar to the local average treatment effect estimated by the IV in the other models.

We estimate the FS IV model with and without the weights (models M3 and M4, respectively). Those weights, used in model M0, are designed to make nonconnected households similar to connected households. Estimated impacts of connection to the grid based on models M3 and M4 are less efficient than the estimates based on the non-IV models because of the use of IV. Estimates based on model M4 may be more efficient than those based on model M3 because of the use of weights in model M3. Model M3 is more similar to model M2 in that both use weights and the same control variables, but estimates based on model M2 are still more efficient (assuming that both estimate the same parameters).

Models M5 and M6: FS and 30-meter distance IVs. In model M5, we add an indicator for whether a household is located within 30 meters of the nearest electric pole as another IV for connection to the grid. As discussed in Chapter VII, a location within 30 meters of a pole could be exogenous to the household in the sense that it reflects the decisions of engineers about where to place poles and a TANESCO requirement for additional pole(s) for connection to the grid if a house is located more than 30 meters away (approximately). In fact, as shown in Figure H.1, we indeed observe a sharp decrease in the probability of connection just above 30 meters. We estimate the FS and 30-meter distance IV model with and without the matching weights, models M5 and M6, respectively. Estimated impacts of connection based on models M5 and M6 are likely to be more efficient than those based on models M3 and M4 because of overidentification, but still less efficient than those based on the non-IV models M0 through M2. Estimates based on model M6 may be more efficient than those based on model M5 because of the lack of weights.

Figure H.1. Probability of connection and household-reported distance from nearest electric pole at follow-up



Source: Tanzania baseline household survey, follow-up household survey, and follow-up household listing data.

Note: Distance from the nearest electric pole is reported by the household in the follow-up household survey, top coded at 100 meters. Only data for nonmoving households are included in the figure, but we see a highly similar pattern when also including movers.

Models M7 and M8: FS, 30-meter distance, and interaction IVs. In the final IV models, we use the indicator for FS status, an indicator for whether a household is located within 30 meters of the nearest electric pole, and their interaction as IVs for connection to the grid. We provide estimates with and without the matching weights (models M7 and M8, respectively). The estimates based on these models are likely less efficient than those based on the non-IV models but may be more efficient than those based on models M5 and M6 because of the use of an additional IV (the interaction between FS status and location within 30 meters of a line). Estimates based on model M8 are likely more efficient than those based on model M7 because it has no weights.

B. Issues related to the measurement of distance

Ideally, we would have measured distance by using baseline household locations based on GPS data. Unfortunately, we were unable to do so because of problems with the baseline GPS data (Appendix F). Hence, we had to rely on follow-up survey data on distance to the electric pole rather than on GPS data, even though GPS data would likely be more accurate in other situations. In our case, however, we were not confident about the accuracy of the GPS data as they were not always collected at the part of the house closest to the pole. In contrast, when recording distance in the follow-up survey, the interviewers explicitly looked for the pole nearest the house and estimated the distance to that pole from the closest part of the house. As shown in Figure H.1, when using survey data, we see a large jump in connection rates at the 30-meter cut-off. We found no clear evidence of such a discontinuity in connection rates at 30 meters (or at any distance for that matter) based on the GPS data. Given the high cost of additional poles, the jump in connection rates based on survey data is consistent with the TANESCO requirement for additional pole(s) for connection to the grid if a house is located more than 30 meters away. This also suggests that the survey data may be more accurate than the GPS data.

Moreover, even though the use of baseline distance would eliminate the possibility that households moved to be near to the pole, it would not rule out the possibility that engineers placed the poles near certain types of households. Such placement would invalidate the use of distance itself as an IV but need not invalidate the use of the 30-meter cut-off controlling for distance. For engineers' pole placement to lead to bias for results based on an IV model, engineers would have had to place the poles so that a disproportionate number of well-off households were located within the 30-meter cut-off while less well-off households were relatively more likely to be located beyond that range. Such a pattern of location is possible, but it is our impression that engineers generally placed the poles near the roads where many households are located regardless of households' financial status. In a related matter, some well-off households do pay for additional poles in order to be connected to the grid. Our understanding is that such an occurrence is rare and therefore does not appreciably bias our estimates. The falsification tests we describe below suggest as much.

The use of survey data on distance comes with two major challenges. First, households living in a community with no lines did not report distance from the nearest electric pole. We set distance to 100 meters for these households, the value at which the distance variable was top coded for all households. It is possible that some of these households were closer to an electric pole in an adjacent community and were connected. Among the nonmoving households, fewer than 1 percent of households in a community without electricity lines (that is, no poles within 40 meters of a house) self-reported that they were connected, suggesting that households connecting to poles not covered in our data may be a relatively minor problem. Second, even though follow-up data for distance is a good proxy for baseline distance for nonmovers, it is not the case for those households that moved within and between communities. We set distance to the nearest electric pole to zero for these mobile households. To ensure that the data for movers do not directly influence robustness checks, we ran our analyses both with and without the movers to see if that changed our results in statistically significant ways. Those results are presented below.

C. Validity of the instrumental variables

Both of the FS status indicator and the 30 meter distance indicator IVs have potential weaknesses. FS treatment status may be in part capturing the economic benefits of having a lower cost of connecting to the grid. Households that would have connected without benefiting from the FS initiative are effectively getting a large cash benefit that they would not have gotten in the absence of the FS. Hence, impacts on income estimated using FS as an instrument could be biased upwards. However, if estimated impacts from the IV model based on using only FS as an instrument (models M3 and M4) and using FS combined with the 30 meter distance indicator as instruments (models M5 through M8) are similar, it would suggest that this source of bias may not be important. This turns out to be the case as discussed below.[113]

The 30-meter distance indicator instrument may also be imperfect; households could move between the baseline and follow-up survey in order to gain access to the electric grid, or engineers could place poles with consideration of which households are located within 30 meters of those poles. To limit the risk associated with mobility and pole placement, we left in-migrants and newly formed households out of our analyses. However, in some models, we included baseline movers—those who were residing in the community at baseline but who moved within or migrated out of the community—in order to ensure that the impacts of FS on connection rates, used in the first stage of our IVs estimation procedure, were unbiased. Exclusion of these baseline movers could create bias for the FS indicator if the prospect of gaining access to the grid influenced mobility decisions. As discussed above, we ran the models both with and without the movers to check that mobility does not affect the main conclusions of the robustness checks.

While neither instrument is ideal, both complement each other in that the weaknesses of one should not affect results for the other. Impacts estimated by using the 30-meter rule should not be affected by the FS initiative in part because FS accounts for a small fraction of the sample. Impacts estimated by using FS as an instrument should not be affected by the 30-meter rule IV because the FS initiative covers all households in a community—regardless of distance from the lines— and FS is randomly assigned.

1. Density test

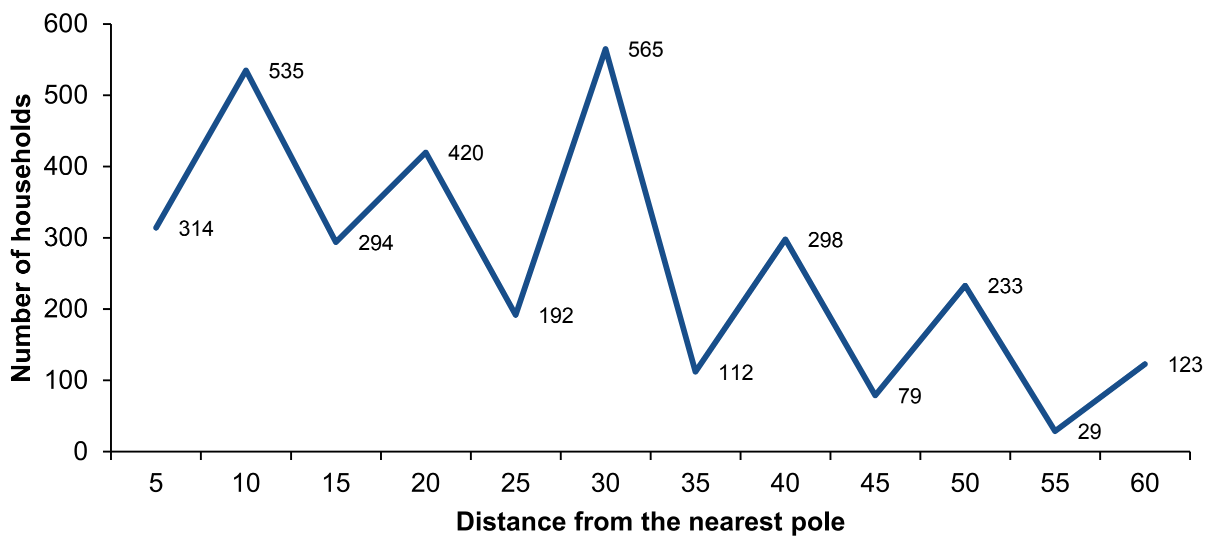
The 30-meter distance indicator may be imperfect as an IV if households that differ on unobserved characteristics correlated with our outcomes are found to be just within the 30 meter cut-off. This could happen if households either moved to be just within 30 meters of an electric pole and/or intentionally misreported that they were 30 meters away from the pole and thus not subject to TANESCO's rule. Further, interviewers might over-report that connected households are located within 30 meters of a pole if they know of the TANESCO rule and assume that connected households must therefore be located within that distance. Last, but not least, engineers may have placed poles with the location of households in mind. For all of these reasons, we might observe a high proportion of households that are exactly at or just below the 30-meter distance from the nearest electric pole compared to the proportion observed just beyond that distance and such evidence might suggest cause for concern regarding the use of this variable as an IV.

[113] If the FS indicator were driving the results for all of the IV models then comparisons across those IV models would not be very informative. However, our data suggest that the 30 meter distance indicator is far more important in the IV models that include both types of IVs. The FS indicator varies only at the community level, and only 27 of the 178 intervention communities are randomly assigned to the FS group. In contrast, the 30-meter distance indicator varies by household. This likely explains why the first-stage F-statistics become much larger when we add the 30-meter distance indicator as an IV in our model (Section 3.b below). It suggests that the 30-meter indicator drives the resulting estimated impacts of connection in the models with both IVs.

Our use of the 30-meter distance indicator as an IV, controlling for distance, was based on the fuzzy regression discontinuity approach (Trochim 1984). In the regression discontinuity context, evidence of a discontinuity in the density function of the running variable, distance from the nearest electric pole, with more households than expected at or just below the 30 meters from a pole location and fewer than expected just beyond the 30 meters from a pole location, would suggest cause for concern. Hence, we investigated this possibility in our data.

We find that the proportion of households whose distance from the nearest electric pole is within 28 to 32 meters (i.e., within a 5-meter band around 30 meters) is higher than the average proportion for all other distances (Figure H.2).[114] For this reason, the resulting estimates do not satisfy the standard assumptions needed for a fuzzy RD. However, the 30-meter distance indicator still satisfies the standard requirements for a valid IV because it passes the falsification tests described in Section 3c. In addition, to assess whether the presence of too many households at or just below the 30-meter threshold affects our conclusions, we estimated some models by dropping all households that reported 30 meters as their location from the nearest electric pole.

Figure H.2. Density test of household distance from nearest electric pole at follow-up



Source: Tanzania baseline household survey, follow-up household survey, and follow-up household listing data.

Note: Distance was reported in integer units at follow-up. This figure uses 5 meter bins centered at multiples of 5 (i.e. from 3 to 7 meters) and excluding households within 2 meters of a pole. Only 46 households reported being that close. This seems plausible given that many households were asked to move to make room for the poles.

[114] A formal t-test of the null hypothesis that the proportion of households whose distance is within 28 to 32 meters of the nearest electric pole is not different from the average proportion is rejected at the 5 percent level. Our test is similar to the McCrary (2008) density test, which would have been applicable if we had continuous distance data. We report the data in 5-meter bands because most observations are reported in the survey in multiples of 5 (i.e., 5, 10, 15, and so forth). Since 95.04 percent of the sample in the 5-meter band around 30 meters reported exactly 30 meters we felt this alternative test was appropriate. The percentages reporting multiples of 5 were similar within the other 5 meter bandwidths used (that is, well over 90 percent).

2. First-stage regressions

One concern with using IVs is that in finite samples they can produce biased estimates if the IVs are weak (Bloom et al. 2010). The estimated impacts obtained from IV models should suffer from little finite sample bias if the IVs are strongly correlated with the endogenous variable (which, in our case, is connection to the gird) and be consistent if the IVs affect household outcomes only through their impacts on the endogenous variable (which, in our case, is connection to the grid). The former is directly testable from the results of the first-stage regressions of the two-stage least squares estimations.

Based on the first-stage regression results, the IVs were all strong predictors of the probability of connection in all first stage models except one. In Table H.1, we present the estimated coefficients of the IVs under models M3 through M8 when estimating the impacts of connection on a household's monthly electricity use. The coefficients on the IVs are all significant at the 1 percent level in all of the model specifications. In addition, the F statistics in all but model M3 are higher than the minimum required first-stage F-statistic recommended by Stock and Yogo (2005) for varying number of IVs and one endogenous variable.[115] We find highly similar results when using the nonmover sample (Table H.2).

Finally, as expected, in the model with interactions between FS status and a location within 30 meters of a line, we see little evidence of impacts of location in an FS community among households not located within 30 meters of a line (the main effect of the FS initiative), as is expected. It appears that our data are not sufficient to estimate the interaction very precisely in the weighted data M7, but we do see a statistically significant interaction in the unweighted data M8.

[115] The minimum required first-stage F-statistic is the critical value for rejecting the null hypothesis that the instruments are weak, which are recommended to be 16.38 for one IV, 19.93 for two IVs, and 22.30 for three IVs. In our case, models M3 and M4 are based on one IV (FS indicator), models M5 and M6 are based on two IVs (FS and 30-meter distance indicators), and models M7 and M8 are based on three IVs (FS and 30-meter distance indicators and their interaction). See Stock and Yogo (2005) for details.

Table H.1. First-stage regression results: Full sample

Instrumental variables	M3 FS IV	M4 FS IV, no weight	M5 FS+Dist IVs	M6 FS+Distance IVs no weight	M7 FS+Dist+Int IVs	M8 FS+Dist+Int IVs no weight
FS status indicator	0.09*** (0.02)	0.10*** (0.02)	0.09*** (0.02)	0.09*** (0.02)	0.03 (0.03)	0.03 (0.02)
Within 30-meter indicator			0.21*** (0.02)	0.22*** (0.02)	0.20*** (0.02)	0.21*** (0.02)
FS status and within 30-meter indicator interaction					0.09 (0.06)	0.11*** (0.04)
Observations	8,771	8,771	8,771	8,771	8,771	8,771
Controls[a]	Yes	Yes	Yes	Yes	Yes	Yes
Weight	Yes	No	Yes	No	Yes	No
F-stat	13.88	26.62	56.74	76.69	41.43	52.62
p-value of F-stat	0.00	0.00	0.00	0.00	0.00	0.00

Source: Tanzania baseline household survey, follow-up household survey, and follow-up household listing data.

Notes: The table shows first-stage regression coefficients from two-stage least squares estimation. Standard errors shown in parentheses are heteroskedasticity-robust and account for clustering at the community level.

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

[a] A continuous measure of distance to the pole is included as a control variable in both stages of the IV models.

Table H.2. First-stage regression results: Nonmovers only

Instrumental variables	M3 FS IV	M4 FS IV, no weight	M5 FS+Dist IVs	M6 FS+Distance IVs no weight	M7 FS+Dist+Int IVs	M8 FS+Dist+Int IVs no weight
FS status indicator	0.10*** (0.03)	0.10*** (0.02)	0.11*** (0.03)	0.10*** (0.02)	0.02 (0.03)	0.02 (0.02)
Within 30-meter indicator			0.21*** (0.02)	0.21*** (0.02)	0.19*** (0.02)	0.20*** (0.02)
FS status and within 30-meter indicator interaction					0.14** (0.06)	0.14*** (0.04)
Observations	7,418	7,418	7,418	7,418	7,418	7,418
Controls[a]	Yes	Yes	Yes	Yes	Yes	Yes
Weight	Yes	No	Yes	No	Yes	No
F-stat	14.28	15.65	56.74	70.08	35.24	47.83
p-value of F-stat	0.00	0.00	0.00	0.00	0.00	0.00

Source: Tanzania baseline household survey, follow-up household survey, and follow-up household listing data.

Notes: The table shows first-stage regression coefficients from two-stage least squares estimation. Standard errors shown in parentheses are heteroskedasticity-robust and account for clustering at the community level.

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

[a] A continuous measure of distance to the pole is included as a control variable in both stages of the IV models.

3. Falsification tests

To test that the IVs affect household outcomes only through their impacts on the endogenous variable (connection to the grid), we performed falsification tests where we examined the impacts of the IVs on baseline values of some of the primary household-level outcomes. If the IVs are exogenous to household decisions, then they should not have impacts on the baseline values.

We examine the impacts of the IVs under different models on the baseline values of monthly electricity use, liquid fuel use, nonelectricity consumption, whether a household is consuming less than $1 per day per person, and whether a household is consuming less than $2 per day per person. We examined results using both the full sample and the nonmover sample. In Tables G.3 and G.4, we show the estimated coefficients from the IVs under the five models for monthly electricity use at baseline for the full sample (Table H.3) or the nonmover sample (Table H.4). None of the 18 coefficients shown in the two tables is statistically significant. For all five variables, we estimated 90 coefficients across the five models and two samples and found that only one was significant at the 10 percent level, suggesting that the IVs are highly likely to be exogenous to household decisions.

Table H.3. Impact of the instrumental variables on monthly electricity use at baseline: Full sample

	M3	M4	M5	M6	M7	M8
Instrumental variables	FS IV	FS IV, no weight	FS+Dist IVs	FS+Distance IVs no weight	FS+Dist+Int IVs	FS+Dist+Int IVs no weight
FS status indicator	3.845 (10.56)	0.820 (3.707)	3.687 (10.57)	0.805 (3.704)	-7.024 (12.30)	-2.305 (2.305)
Within 30-meter indicator			-11.54 (10.17)	1.525 (2.506)	-13.43 (10.40)	0.986 (2.564)
FS status and within 30-meter indicator interaction					16.67 (14.79)	5.255 (4.520)
Observations	8,771	8,771	8,771	8,771	8,771	8,771
R-squared	0.166	0.080	0.167	0.080	0.167	0.080
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Weight	Yes	No	Yes	No	Yes	No

Source: Tanzania baseline household survey, follow-up household survey, and follow-up household listing data.

Notes: Standard errors shown in parentheses are heteroskedasticity-robust and account for clustering at the community level.

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

With use of the IV models, the lack of many statistically significant estimated impacts on baseline values of the outcomes is particularly important; it suggests that, if selection occurred, it would have to be based on changes in well-being (between baseline and follow-up) rather than on baseline well-being. It is not clear how or why such selection would occur. For example, if engineers decided to build poles close to well-off households but not close to poor households or if many well-off households paid for additional poles, then it would be reasonable to expect impacts on baseline income. In contrast, it is difficult to imagine that engineers would have any reason to favor households based on how much their income had increased between 2011 (the year of our baseline survey) and 2013 (when the lines were being built) or why households experiencing a change in income during this time would be more likely to purchase poles than other equally well-off households. For these reasons, we believe that our falsification tests are compelling even though they do not directly capture the possibility of changes over time.

Table H.4. Impact of the instrumental variables on monthly electricity use at baseline: Nonmover sample

	M3	M4	M5	M6	M7	M8
Instrumental variables	FS IV	FS IV, no weight	FS+Dist IVs	FS+Distance IVs no weight	FS+Dist+Int IVs	FS+Dist+Int IVs no weight
FS status indicator	1.421 (9.490)	2.917 (4.548)	1.218 (9.469)	2.900 (4.545)	0.538 (12.40)	-1.029 (2.616)
Within 30-meter indicator			-11.23 (10.04)	1.405 (2.479)	-11.37 (10.38)	0.630 (2.623)
FS status and within 30-meter indicator interaction					1.198 (9.375)	7.367 (6.197)
Observations	7,418	7,418	7,418	7,418	7,418	7,418
R-squared	0.182	0.087	0.183	0.087	0.183	0.087
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Weight	Yes	No	Yes	No	Yes	No

Source: Tanzania baseline household survey, follow-up household survey, and follow-up household listing data.

Notes: Standard errors shown in parentheses are heteroskedasticity-robust and account for clustering at the community level.

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

D. Impacts of connection under different specifications

We estimated impacts of connection to the grid by using the eight models described above to determine if the estimated impacts under the benchmark model M0 (Chapter VII) are sensitive to these variations. We estimated impacts for 10 outcomes—7 primary outcomes from 5 domains and 3 key secondary outcomes from the domain of economic well-being. The outcomes are monthly amount of electricity used by the household from any source, monthly amount of liquid fuel used by the household, hours that children age 5 to 14 spent on studying at night in last 24 hours, fraction of youth age 15 to 24 with health problems (headaches; vision or respiratory problems) in last seven days, fraction of youth age 5 to 14 with health problems (headaches; vision or respiratory problems) in last seven days, fraction of households operating any IGA, annual household nonelectric consumption, share of households consuming less than $1 a day per person, share of households consuming less than $2 a day per person, and annual household income. We also examine these outcomes for the three samples: the full sample, the nonmover sample, and the nonmover sample without those households located exactly 30 meters from an electric pole.

The findings provide no clear evidence of bias in the estimated impacts obtained using the matching approach of the benchmark model M0. Results for the monthly amount of electricity consumed by households, for example, show that the estimated impacts from models M3 through M8 are not statistically different from the corresponding estimate from the benchmark model M0 based on the DWH test in either the full sample (Table H.5) or the nonmover sample (Table H.6) or in the nonmover sample without households at a 30-meter distance (Table H.7). In addition, the estimated impacts in all of the non-IV models are highly similar.

Table H.5. Impact of connection on monthly electricity use: Full sample

Model	Impact	Standard error	*p*-value	DWH t-test (versus M0)
M0: Benchmark	70.44	2.21	0.00***	
M1: T&D Control	71.21	2.23	0.00***	
M2: T&D+Distance Control	73.65	2.17	0.00***	
M3: FS IV	36.00	41.20	0.39	0.84
M4: FS IV, no weight	50.50	17.57	0.01***	1.14
M5: FS+Distance IV	73.57	20.18	0.00***	-0.16
M6: FS+Distance IV, no weight	70.73	6.94	0.00***	-0.04
M7: FS+Distance+Interaction IV	76.12	18.08	0.00***	-0.32
M8: FS+Distance+Interaction IV, no weight	71.86	6.71	0.00***	-0.22

Source: Tanzania baseline household survey, follow-up household survey, and follow-up household listing data.

Notes: Sample size under all models is 8,771. Standard errors are heteroskedasticity-robust and account for clustering at the community level.

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

Table H.6. Impact of connection on monthly electricity use: Nonmover sample

Model	Impact	Standard error	*p*-value	DWH t-test (versus M0)
M0: Benchmark	70.44	2.21	0.00***	
M1: T&D Control	71.02	2.60	0.00***	
M2: T&D+Distance Control	73.57	2.62	0.00***	
M3: FS IV	35.30	41.94	0.41	0.83
M4: FS IV, no weight	40.80	20.13	0.05**	1.47
M5: FS+Distance IV	75.69	20.73	0.00***	-0.27
M6: FS+Distance IV, no weight	70.73	7.29	0.00***	-0.08
M7: FS+Distance+Interaction IV	78.83	17.34	0.00***	-0.50
M8: FS+Distance+Interaction IV, no weight	71.28	7.05	0.00***	-0.16

Source: Tanzania baseline household survey, follow-up household survey, and follow-up household listing data.

Notes: Sample size under the benchmark model M0 is 8,771 and 7,418 under all models. Standard errors are heteroskedasticity-robust and account for clustering at the community level.

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

Table H.7. Impact of connection on monthly electricity use: Nonmover sample without households within 30-meter distance from nearest electric pole

Model	Impact	Standard error	*p*-value	DWH t-test (versus M0)
M0: Benchmark	70.46	2.20	0.00***	
M1: T&D Control	70.04	2.95	0.00***	
M2: T&D+Distance Control	72.55	3.02	0.00***	
M3: FS IV	33.73	51.19	0.51	0.69
M4: FS IV, no weight	35.92	25.67	0.17	1.30
M5: FS+Distance IV	74.89	24.73	0.00***	-0.24
M6: FS+Distance IV, no weight	66.43	7.86	0.00***	0.37
M7: FS+Distance+Interaction IV	79.75	20.25	0.00***	-0.53
M8: FS+Distance+Interaction IV, no weight	67.59	7.73	0.00***	0.21

Source: Tanzania baseline household survey, follow-up household survey, and follow-up household listing data.

Notes: Sample size under the benchmark model M0 is 8,771 and 6,884 under all other models. Standard errors shown in parentheses are heteroskedasticity-robust and account for clustering at the community level.

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

We carry out similar analyses for the nine other variables under the seven alternative models and three samples. We found that, for the 10 outcomes, only 5 percent of the 60 differentials between IV models (M3 through M8) and the main exploratory impact estimates (in M0) are statistically significant at the 5 percent level and that only 10 percent are statistically significant at the 10 percent level (Table H.8). Thus, the number of statistically significant differences is exactly what we would expect by chance alone, suggesting no clear evidence of bias for model M0.

Table H.8. Impact of connection on selected outcomes for robustness check: Full sample

Model	Impact	Standard error of impact	*p*-value	Sample size	DWH t-test statistic (versus M0)
Amount of electricity used by household from any source (kWh)					
M0: Benchmark	70.44***	2.21	0.00	8771	
M1: T&D Control	71.21***	2.23	0.00	8771	
M2: T&D+Distance Control	73.65***	2.17	0.00	8771	
M3: FS IV	36.00	41.20	0.39	8771	0.84
M4: FS IV, no weight	50.50***	17.57	0.01	8771	1.14
M5: FS+Distance IV	73.57***	20.18	0.00	8771	-0.16
M6: FS+Distance IV, no weight	70.73***	6.94	0.00	8771	-0.04
M7: FS+Distance+Interaction IV	76.12***	18.08	0.00	8771	-0.32
M8: FS+Distance+Interaction IV, no weight	71.86***	6.71	0.00	8771	-0.22
Amount of liquid fuel (kerosene, diesel/gasoline, LPG) used by household (liter)					
M0: Benchmark	2.95	4.17	0.48	8771	
M1: T&D Control	2.94	4.05	0.47	8771	
M2: T&D+Distance Control	-0.13	4.54	0.98	8771	
M3: FS IV	-15.63	83.31	0.85	8771	0.22
M4: FS IV, no weight	42.20	65.91	0.53	8771	-0.60
M5: FS+Distance IV	-26.12	41.04	0.53	8771	0.71
M6: FS+Distance IV, no weight	-7.44	32.08	0.82	8771	0.33
M7: FS+Distance+Interaction IV	-20.62	40.39	0.61	8771	0.59
M8: FS+Distance+Interaction IV, no weight	1.15	34.13	0.97	8771	0.05
Hours children (age 5 to 14) spent on studying at night in last 24 hours					
M0: Benchmark	0.20***	0.03	0.00	5824	
M1: T&D Control	0.21***	0.03	0.00	5824	
M2: T&D+Distance Control	0.19***	0.04	0.00	5824	
M3: FS IV	-0.01	0.76	0.99	5824	0.27
M4: FS IV, no weight	0.22	0.35	0.54	5824	-0.05
M5: FS+Distance IV	0.18	0.35	0.61	5824	0.05
M6: FS+Distance IV, no weight	0.03	0.18	0.86	5824	0.95
M7: FS+Distance+Interaction IV	0.31	0.37	0.40	5824	-0.32
M8: FS+Distance+Interaction IV, no weight	0.00	0.17	0.98	5824	1.20
M0: Benchmark	0.00	0.02	0.86	5072	
M1: T&D Control	0.01	0.02	0.64	5072	
M2: T&D+Distance Control	0.02	0.02	0.42	5072	
M3: FS IV	0.50	0.30	0.11	5072	-1.65
M4: FS IV, no weight	0.57**	0.22	0.02	5072	-2.53
M5: FS+Distance IV	0.18	0.17	0.31	5072	-1.02
M6: FS+Distance IV, no weight	0.13	0.09	0.18	5072	-1.37
M7: FS+Distance+Interaction IV	0.24	0.17	0.18	5072	-1.35
M8: FS+Distance+Interaction IV, no weight	0.13	0.09	0.17	5072	-1.40

Table H.8. (*continued*)

Model	Impact	Standard error of impact	*p*-value	Sample size	DWH t-test statistic (versus M0)
Fraction of children age 5 to 14 with health problems (headaches; vision or respiratory problems) in last seven days					
M0: Benchmark	0.02	0.01	0.15	6636	
M1: T&D Control	0.02	0.01	0.16	6636	
M2: T&D+Distance Control	0.03*	0.02	0.06	6636	
M3: FS IV	0.55	0.33	0.11	6636	-1.59
M4: FS IV, no weight	0.49*	0.26	0.07	6636	-1.82
M5: FS+Distance IV	0.21	0.17	0.22	6636	-1.13
M6: FS+Distance IV, no weight	0.26**	0.10	0.01	6636	-2.52
M7: FS+Distance+Interaction IV	0.23	0.18	0.22	6636	-1.15
M8: FS+Distance+Interaction IV, no weight	0.29***	0.10	0.01	6636	-2.65
Fraction of households operating any IGA					
M0: Benchmark	0.02	0.02	0.14	8771	
M1: T&D Control	0.03	0.02	0.11	8771	
M2: T&D+Distance Control	0.02	0.02	0.15	8771	
M3: FS IV	-0.07	0.45	0.87	8771	0.22
M4: FS IV, no weight	-0.05	0.24	0.85	8771	0.29
M5: FS+Distance IV	-0.13	0.15	0.38	8771	1.06
M6: FS+Distance IV, no weight	-0.12	0.11	0.28	8771	1.36
M7: FS+Distance+Interaction IV	-0.05	0.15	0.74	8771	0.51
M8: FS+Distance+Interaction IV, no weight	-0.09	0.10	0.37	8771	1.17
Annual household nonelectricity consumption (TZS)					
M0: Benchmark	1124707.74***	200123.27	0.00	7898	
M1: T&D Control	1153660.53***	202436.74	0.00	7898	
M2: T&D+Distance Control	1221052.22***	196302.07	0.00	7898	
M3: FS IV	2948231.16	6693416.70	0.66	7898	-0.27
M4: FS IV, no weight	2728285.31	2423466.31	0.27	7898	-0.66
M5: FS+Distance IV	1993414.40	1866724.88	0.29	7898	-0.47
M6: FS+Distance IV, no weight	1951116.09**	905909.63	0.04	7898	-0.94
M7: FS+Distance+Interaction IV	1460586.09	1670227.29	0.39	7898	-0.20
M8: FS+Distance+Interaction IV, no weight	2067592.66**	915760.31	0.03	7898	-1.06
Fraction of households consuming less than $1 per day per person					
M0: Benchmark	-0.16***	0.02	0.00	7898	
M1: T&D Control	-0.16***	0.02	0.00	7898	
M2: T&D+Distance Control	-0.16***	0.02	0.00	7898	
M3: FS IV	-0.25	0.54	0.65	7898	0.16
M4: FS IV, no weight	-0.39*	0.22	0.09	7898	1.04
M5: FS+Distance IV	-0.47**	0.22	0.04	7898	1.41
M6: FS+Distance IV, no weight	-0.36***	0.11	0.00	7898	1.84
M7: FS+Distance+Interaction IV	-0.45**	0.22	0.04	7898	1.33
M8: FS+Distance+Interaction IV, no weight	-0.31***	0.10	0.00	7898	1.53

Table H.8. (*continued*)

Model	Impact	Standard error of impact	*p*-value	Sample size	DWH t-test statistic (versus M0)
Fraction of households consuming less than $2 per day per person					
M0: Benchmark	-0.05***	0.01	0.00	7898	
M1: T&D Control	-0.06***	0.01	0.00	7898	
M2: T&D+Distance Control	-0.05***	0.01	0.00	7898	
M3: FS IV	-0.08	0.28	0.77	7898	0.10
M4: FS IV, no weight	-0.21*	0.12	0.10	7898	1.26
M5: FS+Distance IV	-0.13	0.13	0.31	7898	0.60
M6: FS+Distance IV, no weight	-0.12**	0.05	0.03	7898	1.35
M7: FS+Distance+Interaction IV	-0.07	0.12	0.54	7898	0.16
M8: FS+Distance+Interaction IV, no weight	-0.10**	0.05	0.04	7898	0.99
Annual household income (TZS)					
M0: Benchmark	1967359.61**	782532.68	0.02	7245	
M1: T&D Control	1918779.33**	792349.68	0.02	7245	
M2: T&D+Distance Control	2078768.00**	846451.57	0.02	7245	
M3: FS IV	43688026.24	28790301.11	0.14	7245	-1.45
M4: FS IV, no weight	6756105.90	5881776.36	0.26	7245	-0.82
M5: FS+Distance IV	1520124.55	5803384.76	0.80	7245	0.08
M6: FS+Distance IV, no weight	2303942.85	2066801.82	0.27	7245	-0.18
M7: FS+Distance+Interaction IV	167069.23	5729524.32	0.98	7245	0.32
M8: FS+Distance+Interaction IV, no weight	2581297.24	2079009.02	0.22	7245	-0.32

Source: Tanzania baseline household survey, follow-up household survey, and follow-up household listing data.

Notes: Standard errors shown heteroskedasticity-robust and account for clustering at the community level.

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

E. Using Baseline Distance as an IV

In this appendix we used a variable based on follow-up distance as an IV due to problems with the baseline distance described in Appendix E. However, we also examined models that replaced the follow-up GPS IV with one based on the baseline GPS data. In particular, we interacted baseline distance from the nearest new pole with a dummy indicating whether or not the household was within 40 meters of the new pole. Then we used both the distance variable and the 40 meter dummy variables as controls and the interaction term as the IV. This specification was designed to eliminate the need for the baseline distance variable to be as accurate as it would need to be for the specification using the follow-up GPS data. We tested the baseline GPS IV variable to see if it passed the same specification tests that were used for the follow-up GPS data and it did both in the sense that it was a strong predictor of connection rates and in the sense that it did not predict the set of outcomes considered in our falsification tests.

Estimated impacts obtained using the baseline GPS IV differed in a statistically significant way from the matching-based estimates presented in Chapter VII for 8 percent and 11 percent of the estimates at the 5 and 10 percent level of significance, respectively, highlighting the need for caution when interpreting the results in that chapter. As with the follow-up-GPS IV results above, we used 6 different models and 10 outcomes so we had a total of 60 estimates. There are at least two explanations for this apparent discrepancy other than bias—spillover and interactions. Spillover could cause the IV results if living in an electrified community affects outcomes of households that do not connect. We know that this is very likely for certain outcomes, such as perceived safety.[116] It may also be true for other outcomes, such as the availability of electrified businesses. Interactions could matter because the IV model estimates impacts for households whose decision to get connected is affected by the IV whereas the matching-based estimates in Chapter VII apply to all households. If impacts vary across subgroups of households, as suggested by the subgroup results in Chapters V, VI, and VII, then we might not expect the IV and matching-based results to align, even if neither are biased. However, as noted above, it is not clear why such differences would offset bias if bias were there.

While the results based on the baseline-GPS IVs differed from the results based on the benchmark matching model in more cases that would be expected by chance, taking the results of the follow-up-GPS and baseline-GPS IV models together suggests no clear evidence of bias.[117] To summarize, while the results from the baseline-GPS-data-based IVs give reason to interpret the Chapter VII results with caution, we still view the findings presented in Chapter VII on the impacts of connecting to the grid as standing up well to our sensitivity tests and thus, they remain our best estimate regarding the true impacts of being connected.

[116] Perceived safety, if the household had a child attending an electrified school, if the household whose last hospital visited had grid electricity at night, and if the household was electrifiable were all dropped from our exploratory analyses and are thus excluded from this appendix as well.

[117] We had 6 models for each GPS-based IVs and we tested 10 outcomes for each set for a total of 120 different impacts that were compared to the benchmark matching model. In 9 percent of the estimates we got results that differed from the benchmark model at the 5 percent level of significance and in 14 percent of the estimates at the 10 percent level of significance. If we treat the 120 estimates as independent observations, the 9 percent is not statistically different from the 5 percent level of significance and the 14 percent is not statistically different from the 10 percent level of significance. If random variation causes positive correlations across the estimates then we may be over-estimating the statistical significance of the full set, suggesting even more strongly that there is little evidence of bias.

APPENDIX I

ESTIMATING TOTAL NUMBER OF CONNECTIONS

This page has been left blank for double-sided copying.

In this appendix we describe how we obtained our estimate of total connections across all project communities. As discussed in Chapter V, based on the household-level impacts of the T&D lines, we estimate that MCC achieved about 31 percent of the targeted number of connections assumed in an economic rate of return (ERR) calculation MCC produced in 2008. The ERR was based on an estimate of 35,000 new connections in the year after the lines were built. In comparison, we estimate that there were a total of 10,794 new connections to MCC lines by the time of the follow-up survey. We obtained this estimate as follows.

- **Adjusting for sampling and response rate.** The household survey data show approximately 417 connections to MCC lines in the T&D lines intervention communities (including new households and excluding out-migrants). Based on the follow-up survey response rate of 81.6 percent, and survey sampling rate of 16 percent, this suggests a total of around 3,194 such connections in the surveyed communities.
- **Imputing data for missing subvillages.** Just under 81 percent of the surveyed connections were in communities with multiple subvillages. More precisely we estimate that 2,581 of the connections were in such communities. Using the baseline household survey data we estimated that the subvillages we surveyed were expected to contain approximately 72 percent of the households with access to the MCC lines out of the households in all subvillages in those communities. Hence, we multiply the 2,581 by 1.39 (1/0.72) which gives us 3,585 connections. Adding back the households in communities without multiple subvillages (613) gives us a total of 4,198 connections.
- **Adjusting for sampling of villages/*mtaa*.** We had randomly sampled only about 54 percent of the T&D lines communities for our T&D lines sample (182 out of 337 communities). Hence, we can multiply again by 1.85 (1/0.54). This gives us the overall estimate of about 7,773 connections to MCC lines or around 34.4 connections per community estimated to have gotten lines.
- **Comparison communities with MCC lines.** We do similar calculations to come up with an estimate of 544 estimated connections from 20 comparison group communities which were not originally selected for the T&D lines activity but did end up getting MCC lines. They had an average of around 27.2 connections per community that received lines.
- **Imputing data for lines built in communities not in sampling frame.** Our pole data suggest that about 60 of the 182 T&D communities in our sample did not get lines funded by MCC.[118] This implies that roughly 111 communities in the full T&D group (including those not covered in our survey) did not get lines, which is 91 more than the 20 communities in our comparison group that got MCC lines. We assume that an additional 91 communities not covered by our surveys also got an average of 27.2 connections per community in order to

[118] The pole data may over-estimate the number of communities that did not get lines funded by MCC for two reasons. First, if a community has poles but none are within 40 meters of a household, then our data would not capture any poles in that community, and (2) in some instances, the subvillages covered by the household survey may not have been the ones targeted to receive the MCC-funded lines. All villages covered by the community survey were targeted for MCC-funded lines but we identified subvillages for the household survey based on having the highest fraction (within the village) of households expected to have access to any new line (not just an MCC line).

keep the total number of communities getting lines at the original estimate. This gets us to the total of 10,794 connections.

- Thus, we estimate that about 31 percent (10,794/35,000) of the target has been achieved.

In order to impute data for the communities not covered in our sampling frame we assumed that the total number of communities receiving lines was the same as it was in the original plans. This assumption is strong so we explored at least one alternative. In particular, we could have assumed that the communities not covered by our survey got new MCC lines at the same rate as our comparison group. About 11 percent of our comparison group communities got new lines (20 out of 182). There were 6,469 total communities in our baseline sampling frame. That would imply that around 931 communities in total got new MCC lines, almost triple the original plan of 337 communities. This seems implausible; so we stick with the assumption that the total number of communities getting lines remained about the same as the original plans. The relatively high fraction of communities receiving MCC lines observed in our comparison group suggests that our comparison group was selected in a way that matched the intervention group much better than other communities in these regions. Thus, they were more likely to be chosen to receive MCC lines when one of the original intervention communities was dropped than were other communities in these regions.

We do have some additional evidence that aligns with our estimate of 10,794 connections. That estimate is roughly consistent with the 9,830 connections estimate we received from MCA-T referring to the end of June 2014 given that we would have expected some growth between June of 2014 and late 2015 when our follow-up survey was conducted.

APPENDIX J

SUPPLEMENTARY ANALYSES RELATED TO IMPACTS OF ELECTRICITY ACCESS ON EMPLOYMENT BY GENDER FOLLOWING DINKELMAN (2011)

This page has been left blank for double-sided copying.

Dinkelman (2011) found that in South Africa villages with electricity access had female employment to population ratios (age 15-19) about 9 percentage points higher than villages without access. We tried to replicate her analysis. In this appendix we explain why we did not present those results in the main body of our report.

1. Dinkelman (2011) found no clear evidence of a gender difference. Point estimates in the paper based on a linear probability model showed that the impact of access to electricity on women's employment rate was more than double that of men (13.6 percentage points versus 4.1 percentage points). However, the results were much more similar in a logistic model (23.6 and 21.5 percentage points). In neither model was the gender difference statistically significant.
2. The employment rates in Dinkelman's data were under 10 percent for women in the study communities in South Africa. In comparison, they were over 80 percent in our data for the study communities in Tanzania, suggesting very different labor market participation situations for women in these two countries.
3. Dinkelman's analysis is based on unweighted community-level census data. That gives far more weight to small communities than our household-level analyses, and the higher weight to small communities has unclear policy implications. Also the definition of community in her sample may differ from the definition used in ours, where we include neighborhoods (mitaa) in urban areas and sub-villages in rural areas.
4. Dinkelman's employment outcome treated some people who were not working for pay as employed.[119] Our data did not enable us to replicate this aspect of her outcome measure.
5. Even though we did not try to completely replicate Dinkelman's outcome, we did construct an outcome that was designed to be like that in her paper in some ways. The results we obtained are generally similar to the results in the main body of this report. In the main body we included a measure indicating if any adult (age 15 or over) in the household was a "paid employee." We found no statistically significant impacts of line extensions, low-cost-connection offers, or actually connecting on that outcome. The Dinkelman outcome included people who worked for pay even if they were not employees, so we created a new outcome to indicate if any adult (age 15 or over) in the household worked for pay even if they were self-employed (which includes working as a farmer). We also created similar measures by gender, limiting the samples for those outcomes to households with at least one person age 15 or older of the relevant gender: household has at least one female member who works for pay, and household has at least one male member who works for pay. Even though we did find one coefficient significant at the 0.05 level and another at the 0.10 level, the results were generally not statistically significant and we found no evidence of a significant gender difference.

[119] In particular, the 2001 South African Census question asked, "Did the person do any work for pay, profit or family gain…?" The words "family gain" suggest work without pay.

Those results are presented below. The results for the T&D line extensions (Table J.1 below) suggest a positive impact of 2 percentage points overall on working for pay and a larger estimated impact for females than for males, but the gender-difference was not statistically significant. The results in Tables J.2 and J.3 below show that we found no clear impacts of FS or actually connecting on these outcomes.

Table J.1. T&D impacts on employment outcomes

Follow-up outcome	Comparison mean	Impact	*p*-value
Secondary outcomes			
Household has at least one member who is a paid employee	0.18	0.00	0.94
Household has at least one member who works for pay[a]	0.93	0.02*	0.05
Household has at least one female member who works for pay[a]	0.77	0.05***	0.01
Household has at least one male member who works for pay[a]	0.87	0.02	0.10

Source: Tanzania energy sector baseline and follow-up household surveys, and follow-up listing of households.

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 4,467 in the intervention group and 4,430 in the comparison group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

[a] Working for pay includes those who are paid employees, self-employed, and work in farming. The male variable covers only households with males age 15 and over. The female variable includes only households with females age 15 and over.

[b] Time spent at home with family and watching television are components of the measure of time spent on socializing and resting.

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

Table J.2. FS impacts on employment outcomes

Follow-up outcome	Control mean	Impact	*p*-value
Secondary outcomes			
Household has at least one member who is a paid employee	0.17	0.02	0.38
Household has at least one member who works for pay[a]	0.95	0.01	0.41
Household has at least one female member who works for pay[a]	0.81	0.00	0.87
Household has at least one male member who works for pay[a]	0.90	0.00	0.83

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

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 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 specific outcomes. We calculated statistics by using sample weights to account for sampling and interview nonresponse.

[a] Working for pay includes those who are paid employees, self-employed, and work in farming. The male variable covers only households with males age 15 and over. The female variable includes only households with females age 15 and over.

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

Table J.3. Estimated impacts of actually connecting on employment

Follow-up outcome	Not-connected mean	Impact	*p*-value
Secondary outcomes			
Household has least one member who is a paid employee	0.25	0.02	0.15
Household has at least one member who works for pay[a]	0.97	0.00	0.79
Household has at least one female member who works for pay[a]	0.80	0.00	0.90
Household has at least one male member who works for pay[a]	0.91	0.00	0.96

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

Notes: The table shows regression-adjusted impact estimates, controlling for explanatory variables described in Chapter IV and for the lagged (baseline) outcome when available. The analysis sample includes 8,897 households, with 1,189 in the connected group and 7,629 in the nonconnected group. Survey item nonresponse may have resulted in smaller sample sizes for specific outcomes.

[a] Working for pay includes those who are paid employees, self-employed, and work in farming. The male variable covers only households with males age 15 and over. The female variable includes only households with females age 15 and over.

[b] Time spent at home with family and watching television are components of the measure of time spent on socializing and resting.

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

This page has been left blank for double-sided copying.

APPENDIX K

STAKEHOLDER COMMENTS ON DRAFT REPORT

This page has been left blank for double-sided copying.

Table K.1. Stakeholder comments

Location	Stakeholder comment	Mathematica response
General / Exec. Summary	The evaluation only covered line extensions/access. It should be stated up front that it does not cover the impacts of the other investments under T&E that addressed realiabilty, loss reduction, and power quality. Note: substation capacity and line rehabilitation (vs just extensions) were significant elements of the T&D activity costs.	We agree. To help clarify this point we have used new phrases to refer to the impacts evaluated in the report: the impacts of line extensions (in place of T&D activity) and the impacts of low-cost connection offers (in place of FS initiative). We refer to the exploratory impacts as the impacts of actual connections. Also, we have clarified this further by rewriting Box 1 of the executive summary. In addition, we updated the estimated cost of line extensions per connection using the cost breakdowns presented in the MCA-T compact closeout report for line extensions and rehabilitations under the energy project.
	Wherever it says that the T&D Activity did or did not lead to a certain impact, or somewhere up front, it should be clarified that the evaluation is only looking at/referring to impacts in communities that received new lines/ extensions (not other interventions other the T&D activity, although there could have been overlap, in terms of which investments communities benefitted from).	Agreed. See response to comment # 1.
	FS lowered poverty rates: it is not clear how	The mechanishm through which low-cost connection offer (FS) could reduce poverty is that it increases connection rates to the grid, which in turn increases household consumption and income. We found that FS did increase connection rates, and our exploratory analysis also shows that actually connecting to the grid increased consumption and income. The combined effect is reflected in the impact of low-cost connection offers on household consumption, income, and poverty.
	Connection rates: it should be clarified for which population/sample the increase applies (rates within the beneficiary communities?)	We have clarified this at the beginning of the 4th paragraph of the executive summary by saying, "for the households and businesses residing in the communities where these interventions were implemented."
	Impact on connections: how do the results compare with what TANESCO has seen on other line extension projects? Or can a comparison be made with other projects where connections were not included in the project?	Our experience trying to get data on number of connection by geographic units from TANESCO suggests they may not have good data on this topic. In addition, we are not aware of any report or data TANESCO's experience on other line extension projects. No changes were made in the report.
xx	This statement is confusing/unclear: "the estimated impacts of being connected to the grid were even more positive than the impacts of T&D or FS" - the difference could be clarified.	A major difference between the impact of being connected and the impacts of line extension (T&D) and low-cost connection offers (FS) is that the impacts of T&D and FS include impacts for people who did not connect where as the impacts of actually connecting are limited to those who do. However, we agree that the narrative is unclear. So, we have taken out all references to the impacts of being actually connected from the executive summary when discussing the impacts of line extension (T&D) and low-cost connection offers (FS) to avoid confusion, and discuss the impacts of actually connecting in a separate section of the executive summary.

Table K.1. (*continued*)

Location	Stakeholder comment	Mathematica response
xxii	Is it correct to say "The T&D activity also increased the time both men and women spent collecting water and fuel"? Should this be stated as "the [overall] time spent… increased within communities that received new lines under the T&D Activity"	No, that wouldn't be quite accurate since we didn't actually check to see if time spent doing these things increased over time. Rather, we were saying that this time was higher in the intervention group than in the comparison group suggesting that the T&D activity had a positive impact on this use of time. No changes were made in the report.
xxv	This statement should be included in the summary document, up front (this clearly): "Our findings from the T&D and FS evaluation, as well as the exploratory analysis of impacts of connecting to the grid, suggest that the potential benefits of increasing access and connection to grid electricity in Tanzania are considerable and spread across a variety of economic and non-economic outcomes. However, low connection rates in the T&D and FS communities limited the potential benefits." and: "connection to the grid increased household income by about 50 percent while reducing poverty by 16 percentage points, suggesting that T&D may have similar impacts if connection rates rise in the future."	This point is currently on page xxv of the Executive Summary. We think that making this point earlier in the executive summary before presenting the summary of impacts for the line extensions (T&D) and low-sost connection offers (FS) may be confusing to readers. No changes were made in the report.
pp4-7	Description of T&D activity: again, it should be clarified that the evaluation looked only at impact of new lines (access/connections outcome) This section does not speak to the reliability or quality outcomes. Table III.1 on p.34 does state that the subject of the evaluation for T&D was line extensions.	Agreed. See response to comment #1 above.
73	again, on the increase in connection rates: can it be assumed "within the beneficiary communities" is implied?	Yes. We state this more clearly in the 2nd paragraph that we are talking about direct impacts of building the new lines and not indirect effects that might be due to the fact that lines were built in another community nearby.
74	The section on findings re: energy use should be included in the summary doc (not all of it is currently reflected in the summary)	Agreed. We have included the explanation on the substitution between grid and nongrid electricity in the Executive Summary of Chapter V in the section on "energy use". We have also included the no impacts on kerosene use and its possible reason in the same section.
75	It's suprising that no change in use of kerosene was observed. Can more be said about this? With electricity and increased lighting, why did kerosene consumption not decrease? What else is it used (I assume charcoal is the primary cooking fuel)	It is probably not surprising given liquid fuel such as kerosene is already being replaced by dry cell batteries in nonelectrified households in most African countries as Peters and Sievert (2016) suggested. This was already mentioned in the Literature Review chapter. We have now included this explanation in the Executive Summary of the report, the Executive Summary for Ch.V, and in Section A.2 in Ch.V.
81	Can this statement be expounded upon? "The T&D activity increased by about 1.6 hours the time households had grid electricity each day, more than doubling the hours relative to comparison communities; the estimate is statistically significant at the 1 percent level." This appears to relate to reliability of grid supply, as opposed to access/connection.	Not necessarily. The measure includes households that are not connected so it is possible and indeed likely that most of the difference is due to connection rate differences. We added a footnote to clarify this point.

Table K.1. (*continued*)

Location	Stakeholder comment	Mathematica response
82	More of the observations on energy use should be highlighted in the summary document, particularly those relating to efficiency meaning more appliances used or appliances used more, as well as the reduced cost of cell phone charging.	We have included more details in the Executive Summary. Please see response to comment #11 above.
86	the explanation of impacts on access to health facilities is confusing as written; not clear how there's no significant impact on access or distance to facilities with electricity, yet there is a statistically significant impact on "distance from the community to facilities that provided X-ray services, malaria tests, and HIV tests"	One possible explanation is that the line extensions improved the quality of electricity, for example from electricity provided with a generator run for only a few hours per day to grid electricity, which allows the electrified centers to offer these services. We have added this explanation in the report.
152	Correlation with proximity to a pole (within 30m): I doubt households moved to be closer to poles, in the time between when they were installed and the FS offered. Isn't it likely that HH close to the poles/lines were more interested in taking advantage of the FS?	The proximity to the pole is irrespective of whether households got connected. Here, the impact on proximity suggests that a pole is more likely to be within 30 meters of the households in the low-cost connection communities irrespective of households' connection status. We believe that households moving closer to the poles is one of the explanations for this observed result. Moving could be a relatively low-cost endeavor relative to the connection cost subsidy--especially if it just meant moving within an existing property of perhaps 1-2 acres.
153	It could be clarified how the findings on connection, such as "Connection to the grid greatly increased households' use of electricity as expected", differ from those associated with the FS (which also increased consumptions, while the T&D activity as a whole did not)	Please see response to comment #6 above.
156	Under Conclusions, what does this refer to: "we found evidence of significant cost challenges associated with building the T&D lines", and what was learned from this, relevant to the evaluation?	This is based on the comparison we do of the costs of new lines per connection to the estimated impacts of actually connecting on household consumption and income. We have clarified this in the report.
156	The analysis and conclusions indicate no significant impact on HH income, but it's not clear whether HH realized savings on electricity, for a given consumption level (per kWh), due to grid connection. (is it possible they had savings but then reallocated that income)	Our primary outcome in the economic well-being is non-electricity consumption. The point estimate for that impact of line extensions (T&D) on that outcome is negative. Thus, on average we find no evidence that they are transferring any savings to non-electric consumption.
156	Re: "Our findings suggest that connection to the electric grid can significantly reduce poverty and play an important role in furthering the UN's(?) Sustainable Development Goal of reducing the poverty rate at least by half by 2030 (UN 2015)." Why the (?) after UN's?	That was a typo, we have fixed it. Thanks for pointing it out.
157	Re: the conclusion regarding the fact that "other initiatives" under the T&D project may help justify the costs: YES! Of course they do, and not all of the cost was for line extensions. Again, this evaluation does not look at the benefits from the investments intended to improve reliability, loss reduction, or quality of power.	We agree. To clearly specify that we only examined two components of the entire energy sector project, we have used new phrases to refer to the impacts evaluated in the report: the impacts of line extensions (in place of T&D activity) and the impacts of low-cost connection offers (in place of FS initiative). In addition, we have adjusted our estimates of the cost per connection to account for the fact that about 43 percent of the cost was not for line extensions (as shown in the MCA-T compact completion report, 2015).

Table K.1. (*continued*)

Location	Stakeholder comment	Mathematica response
157	The following are major considerations! "The impacts of the T&D activity on access to the grid and the literature we have reviewed for the evaluation suggests that connection rates could easily double in the coming years (Karhamar et al. 2014; Barron and Torero 2016; Winther 2007). Third, even though our estimates suggest that the T&D activity will probably not pay for itself in the short run, it could pay off over several years if the estimated impacts on household consumption or income remain stable or grow and discount rates are not too high."	We agree with the reviewer's observation that these are key considerations for policymakers.
Lessons Learned	These extracts should be included in lessons learned: 1) "... reducing connection costs would increase connection rates and thus might reduce the cost of building new lines." 2) "...focused efforts may be needed to ensure that the increased use of television does not offset any positive educational outcomes." 3)... in the area of health, 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"	We make these points on the last page of our conclusion. Are you asking us to make them somewhere else as well? If so please clarify where. No changes were made in the report.
	Any and all challenges encountered that related to the survey work, the type of data collected or how it was collected should be included in the lessons learned, along with suggestions on how to address these kinds of challenges in future projects. It seems that we did not ultimately evaluate the T&D investments' impacts on loss reduction or outages/reliability because of data problems, and that's unfortunate, given these were among the major, anticipated benefits.	We did share some lessons learned with MCC seprately, which are documented in the MCC Summary of Findings. We think that the evaluation report is not the ideal avenue for sharing such lessons. Conditional on resource availability, we would be happy to have further discussions with MCC about lessons learned on survey and administrative data collection.
	Lessons should include questions for project design related to whether some level of complementary investment in the supply of productive, electricity-consuming equipment/appliances could be a cost effective means of boosting project impact. Ensuring connections is one thing, but fostering productive use of electricity (and/or decreasing the cost of electricity) is also key to increasing income. Public lighting might also be targeted.	We agree that complementary investments can potentially boost the impacts on electrified households and even the probability of household connecting. However, because our evaluation was only attempting to examine the impacts of MCC's current investments related to line extensions and low-cost connection offers, we are unable to say whether other complementary investments would be effctive or not.
	Add: project design should address not only how to ensure connections to new lines, but also opportunities to reduce the real cost of connections (in terms of materials, designs, standards, etc)	Please see response to comment #25 above.

Table K.1. (*continued*)

Location	Stakeholder comment	Mathematica response
	The lessons should tease out/clarify how we should think about impacts on income vs poverty, since there are some conclusions/findings on these that may seem counterintuitive or conflicting.	"The estimated impacts on income and poverty are consistent for the analyses of line extensions (both not statistically significant) and actually connecting (neither statistically significant), but not for low-cost connections (FS). However, while the point estimate for the impact of FS on income is not statistically significant, it was positive and large in magnitude (more than doubling household income). This suggests that the estimated impact on income may have been small relative to the variation in income, making it harder to find statistically significant impact. In comparison the estimated impact on poverty may have been larger relative to the variation in poverty, so we were able to detect impacts there.
	See comment above regarding the need for a longer evaluation period in order to see more benefits to be realized. What is the appropriate evaluation period then?	We agree that a longer evaluation period would have helped. However, this evaluation cannot shed light on the time horizon necessary for realizing higher impacts. We have discussed possible length of time to achieve high levels of connection rates based on the current literature in Ch.II (please see Figure II.1).
	I agree with the conclusion that tariff structure should be considered when looking at how to address the cost and uptake of connections.	Thanks for the observation.No changes were made in the report.
xviii	It is unclear what the differences are between/among T&D activity, FS and connection to the grid. The T&D activity facilitated connection to the grid. The FS created actual connection to the grid. How is connection to the grid different from T&D and FS?	Please see response to comment #6 above.
xxi	"Economic well-being, paragraph 2; was there any attempt to normalize the land value increase that may have been caused by other factors? No reference is made to that issue.	"That is a good point. Unfortunately, we can't distinguish improvements caused directly by grid electricity on land values from indirect effects caused by people investing more in their property in order to take advantage of the availability of grid electricity. A major difference between the impact of being actually connected and the impacts of line extension (T&D) and low-cost connection offers (FS) is that the impacts of line extensions and low-cost offers include impacts for people who did not connect where as the impacts of actually connecting are limited to those who do. We have made major revisions to the executive summary and the report to make this clearer. Please see responses to comments #1 and #6 above. "
xxv	First paragraph, last sentence: recommend revising text to "...low connection rates over the limited time period studied in the T&D and FS communities showed lower than projected benefits."	To incorporate the suggestion, we revised the sentence in question to the following: "However, low connection rates in the communities selected for line extensions and low-cost-connection offers over the limited follow-up period produced lower than projected benefits."
14	In this section and subsequent sections, there is a conflation of the terms access, connection and availability. Recommend carefully considering each term when referring to the target of the interventions given the MCC measurement of electricity consumption as a prime factor driving the economic return.	Thank you for pointing this out. We have reviewed the literature review chapter carefully to ensure that these terms are not used interchangeably and have made changes where necessary.

Table K.1. (*continued*)

Location	Stakeholder comment	Mathematica response
25	Kerosene use for heating does not seem to be analyzed here and in later portions of the report. The lack of reduced kerosene use in some or all locations may relate to its application to heating insofaras it may be less than the all-in cost of using electricity for heating. (see note above regarding page 75)	We do not have direct information on whether households used kerosene for heating. We only collected data on amounts of kerosene use and we did not find any impact on that. If households use kerosene for heating, it is possible that they do not change this behavior when they get connected. Please see response to comment #12 above as well.
33	The key research questions do not include an assessment of the impacts to greater reliability of the existing customers in the T&D locations, not just those in the new electricity lines of the T&D locations. This omission seems to miss a key short term impact in the program logic.	The scope of this evaluation only included the line extensions and low-cost connection offers components of the T&D activity. We have clarified this very clearly in this revised version of the report. Please see response to comment #1 above for details.
150	T&D Impacts. T&D communities should be analyzed according to their proximity to urban centers	The subgroup analysis sections in chapters V, VI, and VII includes impacts for communities that are urban and communities that are rural, and how these impacts differ between the groups.
156	This analysis concluded that the T&D activity and FS initiative did not increase income. There is no statement whether it reduced costs. Was this studied? If not, perhaps it should be included in future impact evaluations.	We do not present impacts of T&D and FS on cost of energy directly. We estimated impacts on a large number of related outcomes, in particular use of different types of fuels (including generators, liquid and solid fuels). We could have estimated impacts on the average cost of energy, but it would have required a set of strong assumptions.
Lessons Learned	The estimate of connections for ERR appears to be only for first year connections. An estimate of connections over the life of the MCC investment should be quantified in order to evaluate the total economic benefit of T&D program.	We did send MCC a memo on the ERR for the Tanzania energy project a few years ago. MCC did not ask us to update ERR calculations on this evaluation. It would likely require substantial amount of effort to update the ERR. We did include an estimate of the impact of the line extensions on total connections which could be used to inform ERR calculations.
	Impact evaluation may benefit from including the additional system reliability from an investment (SAIFI and SAIDI values). The absence of this information means that certain relevant short term impacts are not quantified.	These outcomes would have been far more important had we been asked to focus on rehabilitation of existing grid infrastructure rather than the new lines. It would have required us to select a different sample of households, and/or rely on data from the ulitily which was not readily available. That said, we did present data on power surges reported by survey respondents in relation to the discussion on impacts of line extensions on outcomes in the connection rates domain (in Chapter V).
pg 1 (Exec Summary)	Typo in box on first page of exec summary	Thanks. We have fixed the typo.
p 17 (Exec Summary)	there needs to be a clear statement after introduction of the exploratory analysis that none of these findings are attributable to MCC's investment, but rather reflect the benefits of grid connection. If it's not explicit, readers may misunderstand that the connections impacts are MCC impacts.	To clearly distinguish between the evaluation of the MCC-funded activities and the exploratory analysis, we have taken out all references to the impacts of being actually connected from the Executive Summary when discussing the impacts of line extension (T&D) and low-cost connection offers (FS). We have summarized the exploratory analysis in a separate new section in the Executive Summary towards the end and have clarified that the results of this analysis do not assess the impacts of MCC's investments in Tanzania.
Figure ES.2	perhaps label each bar as T&D and FS	Good catch. We have included labels in both ES.2 and ES.3.

Table K.1. (*continued*)

Location	Stakeholder comment	Mathematica response
pg 101 of report	typo: It did not have, however, impact total household nonelectricity consumption.	Thanks. We have fixed the typo.
	This is probably too simple of an analogy, but it seems that TZ I built two of the three legs needed for the stool. The assumption of “build it and they will come” did not come true- hence the missing leg. But given the positive economic benefits of grid connection- I think we should highlight that the MCC investment was foundational to this increase- even if just one leg of the stool.	We agree that the MCC investments played some role in the estimated impacts of connecting to the grid. However, those estimated impacts are based on non-MCC lines as well as on MCC lines and also ignore any possible impacts on non-connected households. For this reason we have downplayed the connection between MCC investments and the impacts of actually connecting.
	it seems MCC in the future should ensure connections alongside the foundational T&D investments. As all of us recall this was debated endlessly in the summer of 2015- hopefully this report provides the data to support a comprehensive plan vice just “build it and they will come”. Maybe it’s MCC paying for it, or requiring the host government to subsidize, but ultimately the low incomes of rural residents mean the relative high costs of connections, wiring, and appliances are too prohibitive to see the change we had hope to see.	Thank you for sharing the observation. No changes were made in the report.
	Despite its comprehensiveness , I think the report misses a few key contextual details that might help frame the results better. Most notably, the report focuses almost exclusively on connecting new customers to the grid and says little about the upgrades to the existing infrastructure, such as the substations. As originally described in the compact, the purpose of the Distribution Rehabilitation and Extension Activity was to “rehabilitate existing power distribution assets and to extend the distribution network.” The substations and associated network improvements were not simply a prerequisite to the extensions, but they also were intended to provide benefits in power quality and reliability to existing customers. Although we will have a better idea after the models are updated, it is possible that the activity was economically viable even though we realized only a third of the expected new connections. There is one small section in the report that acknowledges this: “The T&D activity involved a range of initiatives—in particular, rehabilitation of substations that help transmit and distribute electricity. It is possible that the other initiatives may help to justify the costs of constructing new T&D lines.” (p. 157)	We agree. In response, we have made major revisions to the executive summary and the report (particularly in the concluding chapter) to make this clearer. Please see response to comment #1 above.

Table K.1. (*continued*)

Location	Stakeholder comment	Mathematica response
	Even if the benefits were sufficient to justify the costs, the low connection rates are clearly disappointing and an opportunity for learning. Although the report mentions the increased connections resulting from the financing scheme, it also notes that, "even if all T&D communities received low-cost connections, the number of connections originally assumed would still have not been achieved." (p. xviii) The report identifies the gap, but it does not probe the reasons for it, beyond stating that the original ERR model estimated 35,000 new connections within a year of construction. However, the Investment Memo and the compact's Annex III had the same target of 35,000 connections in Year 5, so the team must have seen those estimates as plausible at the time. What caused them to be so inaccurate? Were they simply overly optimistic estimates? Were there too many unknowns to project them with any certainty? Would they have been achievable if implementation had been faster? It may be beyond MPR's scope of work, but it might be a good learning exercise for MCC to undertake internally.	Thank you for the observations. As noted in the comment, addressing these questions is beyond the scope of the evlauation. No changes were made in the report.
General	More awareness compaign should be invested during implementation of the projects, thus connection rates could increase	Thank you for your observatation.
	Records should be taken during the connection of customers under the T&D and FS activities, instead of taking random customers and assumptions for report evaluation.	It would not be possible to have baseline data if this method were used.
	It should be noted that, Government of Tanzania (GOT) knew that reduction of connection cost will increase connection rates, thus customers connected during the implementation of rural electrification projects connected by Tsh. 27,000/=. Either GOT removed monthly service charge when buying electricity.	In our literature review we discuss the effects lowering connection fee on connection rates in different countries. We did not have any report covering the rural electrification projects mentioned here.
Pg 100	Healthy and Safety : children in the FS communities had more reported illness-----The report related this with TV watching and that more time spent at home could cause health problems. This conclusion may need further explanation.	Additional explanations are provided in the main body of the chapter, where we said, "These results are plausible in part because the FS initiative increased television watching but did not appear to reduce kerosene use or indoor pollution (reported below). Therefore, if increased television watching increased the amount of time spent indoors near polluting fuels, it could have worsened health outcomes. Health outcomes measured included having difficulty breathing; experiencing wheezing, coughing, sneezing, sore throat, nasal discharge, or congestion; and having problems with vision---all of which may be related to indoor air pollution."

Table K.1. (*continued*)

Location	Stakeholder comment	Mathematica response
Pg 100	The perception of safety persisted for three summary measures of safety. What are these three summary measures.	We have revised the discussion of FS impacts on safety in the summary of the chapter to address the comment: "Respondents in communities with the low-cost connection offers, however, generally felt safer than those living in communities that did not receive the offer. We asked households if they thought communal light was sufficient, if they felt safe walking at night, if they felt that the community lights helped reduce crime and keep them safe from animals at night. We found that the perception of safety persisted for three summary measures of safety: 17 percent responded feeling safe on all four questions of safety, 63 percent on more than half of the questions, and 87 percent on at least one question. The impacts of low-cost connection offers were 5, 7, and 16 percentage points, respectively. "
Pg 103	Given that many dwellings are made of basic materials, moving existing dwellings could be relatively cheap. Definition of basic materials could help so as to have a common understanding to all readers	Basic materials used in building dwellings include grass, earth/mud, sundried and baked bricks, timber, bamboo, iron sheets, cement bricks, and stones. Electrifiable dwellings could not have grass/thatched roof.
Pg 149	The evaluation used both community- and household-level data that were collected in fall 2011. It is better to put the months when the data were collected rather than "fall" for most of Tanzanian to understand.	Thanks for pointing this out. We provide exact dates for the follow-up survey in the data collection section of Chapter IV at the beginning of the description of each dataset. We have deleted all references to "fall" throughout the report.

Note: Location information is based on draft of the report that was reviewed by stakeholders.

This page has been left blank for double-sided copying.

This page has been left blank for double-sided copying.