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REPORT

Evaluation of the Kigoma Solar Activity in Tanzania: Final Report

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LIST OF ACRONYMS AND TERMS

AC	Alternating current
BCG	Bacillus Calmette-Guerin (tuberculosis vaccine)
BMU	Beach Management Unit
Camco	Camco Advisory Services
DPT	Diptheria, pertussis, and tetanus vaccine
EDI	Economic Development Initiatives Limited
GDP	Gross domestic product
kg	Kilogram
kWh	Kilowatt hour
LPG	Liquefied petroleum gas
MCA-T	Millennium Challenge Account—Tanzania
MCC	Millennium Challenge Corporation
MWp	Megawatt peak
NGO	Non-governmental organization
PAYG	Pay-as-you-go
PCV	Pneumococcal conjugate vaccine
PV	Photovoltaic
SACCO	Savings and Credit Cooperative Organization
SHS	Solar home system
SMS	Short message service
TZS	Tanzanian shilling [1 USD = 1,634 TZS in 2013; 1 USD = 2,126 TZS in 2015]
W	Watt

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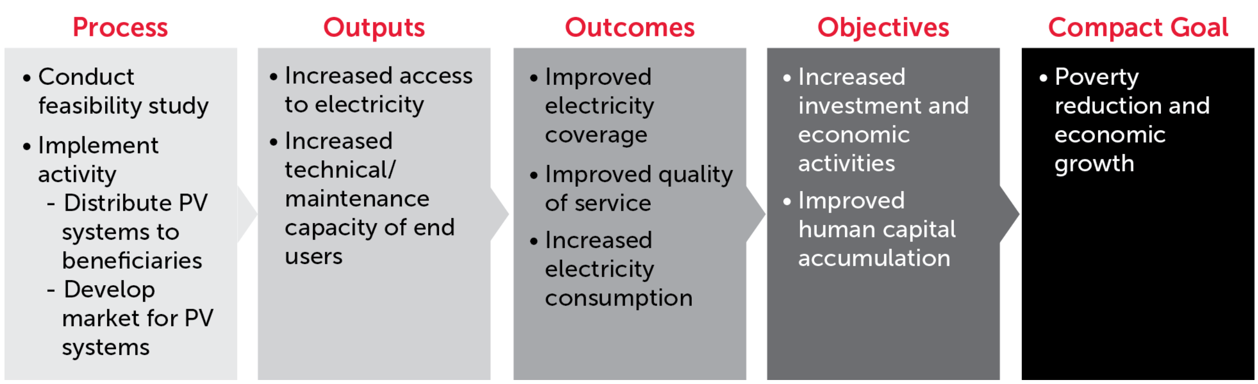
EXECUTIVE SUMMARY

Improving access to high quality electricity can be a key driver of economic growth and household well-being. In an effort to promote economic growth and reduce poverty in Tanzania, the Millennium Challenge Corporation (MCC) funded an energy sector project to increase the availability of reliable, high quality electricity to people in Tanzania. The Kigoma solar activity, one component of the energy sector project, was designed to promote solar power systems in the Kigoma region of western Tanzania. The activity provided solar photovoltaic (PV) systems for schools, health centers, and village markets, and supported the sale of systems to fishers, households, and individual businesses, with financing through local credit institutions. Supporting components included marketing of the solar systems and information on their benefits; training of installers, vendors, and end users; and maintenance and post-sale services, all aimed at developing a market for solar PV systems in the Kigoma region. The activity was expected to affect key outputs and outcomes and to reduce poverty through economic growth, as described in the logic model below.

Figure ES.1. Activity logic for the Kigoma solar activity



The Kigoma solar activity is well aligned with the Tanzanian government's interest in expanding access to electricity to promote economic growth. Tanzania's National Electrification Program Prospectus includes plans to increase electrification rates to 50 percent by 2020, and solar-installed capacity to 100 megawatts by 2025 (Harrison et al. 2016; Ministry of Energy and Minerals 2014). Thus, solar power is expected to make an important contribution to increasing access to energy in Tanzania, especially in rural areas. In recent years, the development of off-grid solar power services in Africa has also received increasing support from the international community through initiatives such as the Power Africa initiative by the U.S. government, the Lighting Africa initiative by the World Bank Group, and the Energy Africa campaign by the U.K. Because of the increased focus on solar power in Tanzania and across Africa, findings from the Kigoma solar activity provide some useful insights into the implementation of solar programs and their ability to expand access to electricity and reduce poverty.

Mathematica Policy Research recently completed a performance evaluation of the Kigoma solar activity. The specific questions this evaluation sought to answer were:

1. How was the Kigoma solar activity implemented?

2. How did outcomes differ at follow-up and change over time for the targeted group selected to receive the Kigoma solar activity versus the nontargeted group?

We addressed these questions by comparing outcomes among survey respondents who were targeted for the Kigoma solar activity and a set of nontargeted comparison respondents at two separate time points: shortly after the activity had been implemented (referred to as the "interim survey"), and two years later (the "follow-up survey").

Findings

Implementation

Implementation generally occurred according to plan, with some key challenges. The seven types of individuals and institutions targeted by the Kigoma solar activity are summarized in Table ES.1. At follow-up, we found that implementation was generally successful, with most targeted institutions receiving solar PV systems funded by the Millennium Challenge Account-Tanzania (MCA-T) as expected. Schools, health facilities (dispensaries and health centers), and businesses in village markets generally received access to solar PV systems according to plan, and individual households and businesses purchased systems through Savings and Credit Cooperative Organizations (SACCOs).

School solar system

Table ES.1. Key components of the Kigoma solar activity

Respondent type	PV system and purpose	PV system capacity	Number targeted to receive systems
1. Schools	Metered AC electrical system for lighting classrooms and offices, computer/TV use, and cell phone charging	3 kilowatt hours (kWh) per day	45 schools
2. Dispensaries; 3. Health centers	Metered AC electrical system for lighting and media services, and cell phone charging; Vaccine refrigerator system for storing BCG, measles, and polio vaccines, as well as other vaccines as needed	1 kWh per day	116 dispensaries; 14 health centers
4. Fishers	Encouraged to purchase systems through beach management units (BMUs)	0.45 kWh per day (powering 5 LED lamps for 9 hours)	38 BMUs
5. Businesses in village markets	Utilized power from village market systems. Village markets received electrical systems to provide general lighting in the market and lighting for individual businesses.	2.6 kWh per day	25 village markets
6. SACCO businesses; 7. SACCO households	Encouraged to purchase unmetered Pico Solar PV systems and Solar Home Systems through SACCOs that could be used for a variety of home and small business needs	20–50 Watt peak	N/A

Source: Kigoma solar baseline and interim performance evaluation report (Busalama 2013).

However, the activity faced some key implementation challenges, some of which limited our ability to evaluate certain components of the activity. For example, during the marketing phase, short message service (SMS) messages were intended to provide an important way to disseminate information about the activity to large audiences, but in the follow-up survey, we found that no respondents had received these messages. This may be the result of a translation issue in the survey, but it may also be that these messages were not appropriately targeted, or there may have been other reasons why they were unpopular among respondents. There also appears to have been very limited uptake of solar PV systems among fishers because no fishers in our study sample reported having participated in the activity, though the interim report did find some use among fishers (Busalama 2013). Because of this, we were unable to assess how the activity affected fishers' operations in these communities and we omit fishers from most of our analyses unless noted otherwise.

Solar PV use was common among those who received MCC-funded systems. All targeted health centers and dispensaries, and 80 percent of targeted schools, were using their MCC-provided solar PV systems at the time of the follow-up survey. Use of MCC-funded PV systems was lower among market businesses, individual businesses, and households (Table ES.2).

Table ES.2. Installation of MCA-T solar systems among targeted respondents

Respondent type	Number of targeted respondents	Received MCA-T PV system	Currently using MCA-T PV system
Schools	10	100%	80%
Health centers	6	100%	100%
Dispensaries	14	100%	100%
Village market businesses	12	92%	67%
SACCO businesses	14	71%	57%
SACCO households	15	93%	53%
Fishers	8	0%	0%

Source: Kigoma solar follow-up survey (2015)

Notes: Targeted respondent sample size = 71. Sample sizes for some variables may be smaller due to nonresponse.

*/**/***Estimate is significantly different from zero at the .10/.05/.01 level using a two-tailed test.

As use of solar PV systems grows, so do expectations for their performance and capacity. Our implementation findings indicate that solar PV systems are being used and are helping to meet the energy needs of most respondents in the targeted communities. The use of solar PV systems increased slightly over time among both targeted and nontargeted respondents, which suggests that the systems are growing in popularity. However, the percentage of MCA-T system users who reported that their solar PV systems met their energy needs fell over time, from 42 percent in the interim survey to 31 percent in the follow-up. This suggests that as solar PV systems become more common and as electricity becomes cheaper and more efficient, community members' needs and expectations regarding the availability of electricity may be growing and/or that the systems may be degrading over time.

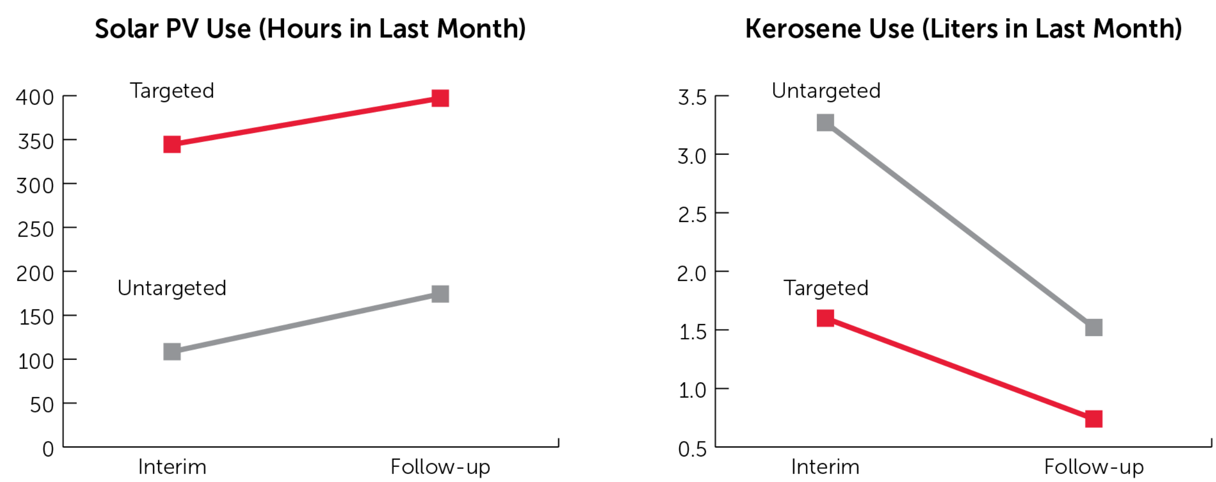
Solar PV systems face quality issues, and a lack of maintenance and repair training may limit their utility and popularity. As the demand for solar PV systems grows, it will be important for providers to ensure that the systems available to users are of high quality and remain functional. Our implementation findings suggest that although MCA-T-funded systems may have performed better than other systems, all systems experienced problems fairly frequently, and only a small proportion of targeted respondents received the maintenance and repair training that was designed to be a component of the Kigoma solar activity.

Performance

The use of solar PV systems increased over time, among both targeted and nontargeted respondents, and was consistently high in the targeted group at interim and follow-up. The growing amount of solar PV use in the nontargeted group may reflect the fact that other donors and implementers were working on solar programs in the Kigoma region at the same time, and may also point to the fact that the demand for these systems are growing in the study area (Figure ES.2).

Liquid fuel use was lower among targeted respondents than nontargeted respondents both at interim and at follow-up, which is consistent with the hypothesis that solar PV systems could help to meet many of the same energy needs that liquid fuel sources typically meet, such as providing light and powering appliances (Figure ES.2).

Figure ES.2. Solar PV and kerosene consumption



Source: Kigoma solar interim survey (2013) and follow-up survey (2015).

Findings from the performance domains provide limited evidence of association between the Kigoma solar activity and improvements in outcomes related to investments, economic activities, and human capital accumulation for specific respondent types. Note that our small sample sizes limit our ability to assess these outcomes deeply. After controlling for respondent type, we found no statistically significant differences between targeted and nontargeted respondents in the number of staff or hours of operation of schools, health facilities, or businesses; per capita household income; or the availability of vaccine refrigerators at health facilities. We found that although most targeted and nontargeted health facilities had vaccine refrigerators available, key vaccines were more commonly found in targeted health facilities than in nontargeted facilities.

Conclusions

The growing focus on improving access to electricity in sub-Saharan Africa, and in Tanzania in particular, has provided the political will necessary to test and develop programs to deliver electricity to rural and other hard-to-reach populations. Given the high costs associated with expanding access to grid electricity and the falling cost of solar energy worldwide, programs such as the Kigoma solar activity may offer a relatively low-cost and effective way to bring electric energy to many rural Tanzanians. Such efforts could help change how people and institutions use energy sources, reduce energy costs for individual households and businesses, enable schools and health facilities to serve people better, and ultimately reduce poverty.

Our findings suggest that the Kigoma solar activity has achieved some of these expected outcomes. Specifically, the overall high use of and satisfaction with solar PV systems, coupled with some changes in the consumption of liquid fuels, suggest that the activity may have helped to encourage solar energy use. Although there is some evidence to support the hypothesis that increased solar energy consumption could help lead to longer-term outcomes, such as improved facility operations and increased income and revenues, our results in this area were generally very imprecise.

Our study provides useful information on solar energy use, and although our evaluation was not a rigorous assessment of the Kigoma solar activity's impacts, it provides a basis for evaluations of future efforts to expand access to solar energy. Future evaluations that allow for longer-term assessments and more rigorous methods could help to produce more rigorous evidence on how expansion efforts work and to what extent they can be used to meet the energy needs of sub-Saharan Africa.

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I. INTRODUCTION

Many researchers have found that improving access to high quality electricity can be a key driver of economic growth and household well-being (Barnes 2014; World Bank 2008). In Tanzania, only about 18 percent of all households on the mainland had access to the national electricity grid in 2011–2012, and the rate was just 4 percent in rural areas (NBS 2014). In addition to the low level of electrification in the country, the power that is available is subject to frequent surges and interruptions in service. The country's gross domestic product (GDP) per person is under US$1,000 and about one-third of the mainland population lives in poverty (World Bank 2016; MoF 2009). As in many other developing countries, lack of access to affordable and sustainable sources of energy in general, and to electricity in particular, is a major barrier to spurring economic growth and reducing poverty in Tanzania.

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 has four key elements: the promotion of solar power systems in the Kigoma region of mainland Tanzania, also referred to as the Kigoma solar activity, and three other activities associated with the use of grid electricity. Together, these activities were designed to increase the availability of reliable and high quality electricity to people in mainland Tanzania and Zanzibar. The Kigoma solar activity was a relatively small component of the energy sector project, costing about $11M in total (MCA-T 2015).

In this evaluation report, we focus on the Kigoma solar activity.[1] We describe how it was implemented and how energy use and other outcomes for targeted respondents changed over time relative to nontargeted respondents two years after completion of the activity. We examine data from schools, health centers, health dispensaries, businesses in village markets, fishers, and independent businesses and households to assess how the activity was implemented and its contribution to affecting key outcomes such as electricity consumption, investment, human capital accumulation, and poverty reduction.

A. Overview of the Kigoma solar activity

The Kigoma solar activity was designed to address a range of energy needs in the Kigoma Rural and Kasulu districts of the Kigoma Region, where energy infrastructure and access to grid electricity is limited. The activity was developed as a substitute for the eight mega-watt Malagarasi hydropower activity that was postponed in December 2009 due to biodiversity risks identified by an environmental analysis of the proposed worksite (MCA-T 2015). The Kigoma solar activity covered provision of solar photovoltaic (PV) systems for certain public institutions (schools and health centers) and village markets, provision of resources for solar-powered night fishing systems for fishers, and the sale of solar systems for household and small business use with financing through local credit institutions. Supporting components included marketing of the solar systems and information on their benefits; training of installers, vendors, and end users;

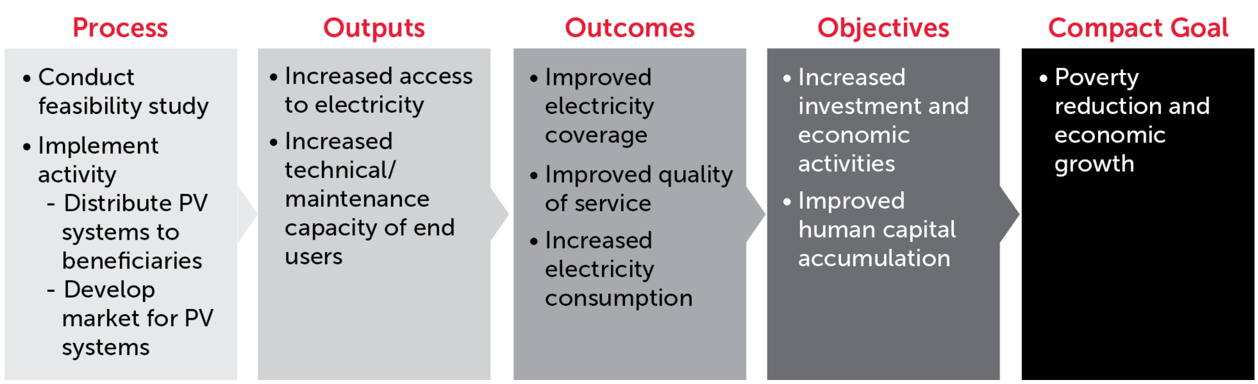
[1] Mathematica Policy Research also conducted an evaluation of the T&D activity and the FS initiative (Chaplin et al. 2017 and 2012) and an evaluation of the Zanzibar cable activity (Hankinson et al. 2011; Schurrer et al. 2015).

and maintenance and post-sale services, all aimed at developing a market for solar PV systems in the Kigoma region. MCC invested about $11 million in the Kigoma solar activity; this covered the installation of a total capacity of 242 megawatt peak (MWp) and 310 pico solar lamps to potentially advance the household market for solar systems in Kigoma region (MCA-T 2015). The activity was implemented between March 2012 and September 2013 by Rex Energy, with marketing support from Camco.

B. Activity logic

The key components of the Kigoma solar activity revolved around the design and implementation of the processes required to finance and distribute solar PV systems to key individuals and institutions. These components, summarized in Figure I.1, were expected to affect a range of outputs, outcomes, and long-term objectives. Key outputs included access to electricity (measured through the number of solar PV systems installed) and technical capacity of end users (measured through the number of users who reported receiving any training). Expectations were that these outputs would in turn lead to improved key outcomes such as electricity coverage (measured through the use of solar PV systems), quality of service (measured through the availability of power and functioning of solar PV systems), and increased energy consumption (measured through the consumption of electric and non-electric energy sources). These outcomes would in turn influence respondent type-specific long-term objectives, such as the revenue earned by businesses and fishers, the availability of vaccines at health facilities, the availability of after-hours study programs in schools, and per capita household income.

Figure I.1. Activity logic for the Kigoma solar activity



Thus, the Kigoma solar activity was designed to improve electricity coverage and increase consumption of electricity, which would in turn increase economic activities by businesses and individuals, as well as access to education and medical services, all of which will contribute to poverty reduction and economic growth. For the purposes of this report, we consider all key outputs, as well as key outcomes related to the availability and quality of solar energy, to fall under "implementation domains." Outcomes related to other electricity consumption, as well as all long-term objectives, are considered "performance domains." These domains are described in more detail in Chapter II.

C. Literature review

Recognizing the importance of access to electricity for economic growth, the Tanzanian government has set out a National Electrification Program Prospectus, with plans to increase electrification rates to 50 percent by 2020, and solar installed capacity to 100 megawatts by 2025 (Harrison et al. 2016; Ministry of Energy and Minerals 2014). Solar power stands to make an important contribution to increasing access to energy in Tanzania, especially in rural areas. The country's solar power potential is higher than Europe's (800 to 2,000 kWh per meter squared), with an estimated range from 1,600 to 2,400 kWh per meter squared (SolarGIS 2014). In recent years, the development of off-grid solar power services in Africa has also received increasing support from the international community through initiatives such as the Power Africa initiative by the U.S. government, the Lighting Africa initiative by the World Bank Group, and the Energy Africa campaign by the U.K. With the increased focus on solar power, the body of literature covering different topics of solar power in Africa is growing.

1. Barriers to purchasing and using solar power

The prices of natural gas and oil have been falling in recent years, which may reduce demand for solar power to some extent. However, technological improvements in solar power generation and batteries, and increased investments by many countries, including developing countries such as China and South Africa, have supported price drops for solar power (Nyquist 2015; Koch 2016). In addition, grid electricity is not likely to be made available in rural parts of developing countries for many decades. Hence, demand for solar power in these areas is likely to continue for years to come, if not indefinitely.

Several studies have highlighted the importance of providing solar PV users with training on how to properly use the systems. De Groot (1997) highlights this on the basis of experience in Kenya developing and running training courses for solar entrepreneurs in rural areas. Odraczek (2011) explains that one of the obstacles to the development of off-grid solar power markets in Tanzania is that users do not have experience with PV technology and 12-volt direct current appliances. Experiences in South Africa also indicate that solar home system (SHS) users need to be educated on the optimal usage of systems based on the manufacturer's specifications (Azimoh et al. 2014).

Another barrier to the dissemination of solar PV systems has been a lack of local sales and repair services (Nicklas 1998). In Tanzania, components such as modules, batteries, and inverters are usually only available in major towns. High transaction costs and poor transportation infrastructure make it costly for wholesalers and retailers to operate in rural areas (Ondraczek 2013). In Tanzania's Lake Zone, there has not been a lot of investment in firms in order to ensure long-term supply of solar systems (Harrison et al. 2016). A study of SHS users in Namibia found that access to high quality systems and good technical services was key in the promotion of SHS. Technicians were able to successfully market the systems to rural households by offering both information and dependable technical services (Wamukonya and Davis 2001). Efforts to improve access to solar power markets and services have been implemented in East Africa. For example, Burris and Hankins helped to develop the solar PV market in Kenya in the 1980s by conducting demonstrations, training local PV system technicians, and preparing PV system technical tools and guide books (Duke et al. 2002; Hansen et al. 2014).

Although the demand for solar PV systems continues to grow (Ondraczeck 2013, in Tanzania and Kenya), solar power's limitations have affected demand for it as a reliable off-grid electricity source. One limitation has to do with the wide range of solar PV systems, each with different generation capacities. For example, small pico-systems, typically with 1–10 peak wattage, include solar lanterns, LED lamps, and solar chargers, and are used for lighting and charging batteries and cell phones. Solar home systems, which typically have 0–100 peak wattage, address off-grid electricity demand by households in remote areas (Hansen et al. 2014). Households in Namibia that use SHS indicated that energy limitations prevent them from using their systems longer and for additional services (60 percent of the 53 households interviewed used the systems to operate television sets) (Wamukonya and Davis 2011). In Kenya, appliances that consume more energy, such as refrigerators and electric cookers, cannot be used with the solar PV options available to rural households, which typically have peak wattage of less than 25W (Jacobson 2007). In fact, the majority of solar PV systems sold to date in Africa provide less than 10W and can only be used for lighting and phone charging (Harrison et al. 2016).

Small and micro-enterprises in rural areas of sub-Saharan Africa that have solar power typically have systems with 40–100 peak wattage that can only be used for lighting and powering low-voltage appliances. These solar PV systems fail to meet the users' energy requirements, which are typically 100 to 1,000 times higher than what these systems can provide (Karekezi and Kithyoma 2002). A second limitation of solar PV systems is that they do not provide consistent power. Unpredictable changes due to cloud clover make solar power intermittent. Depending on the type of system, the intermittency of solar power can be addressed through backup generation and additional system reserves, but this makes reliance on solar power more costly (Baker et al. 2013).

2. Strategies employed to bring solar power to developing countries

South Africa has the largest solar market in Africa and is a key location for solar energy investments, including solar plants (Amankwa-Amoha 2015). However, in terms of per capita installed capacity of solar PV systems, Kenya is the region's leader, with other African countries like Tanzania and Uganda also rapidly growing. In the past, government and donor-supported projects primarily drove the diffusion of PV, but, in recent years, countries in sub-Saharan Africa have moved toward a more market-based diffusion with private-sector involvement (Hansen et al. 2014). One key development has been solar PV's progression towards "grid-parity" by way of a new market for large-scale grid-connected PV plants (Bazilian et al. 2013). The "grid-connected PV market" includes capital-intensive plants that are owned or operated by independent power producers (oftentimes foreign investors). Solar panel assembly plants are also popping up in different countries, including Kenya, Ethiopia, Senegal, and South Africa (Hansen et al. 2014).

Amankwa-Amoha (2015) identifies five solar power scale-up models in Africa:

1. **State-led**. National governments are providing enabling frameworks to attract investments in solar power, including special tax regimes, subsidies, and feed-in-tariffs (also see Hansen et al. [2014]). For example, South Africa recently proposed a large solar park that combines both PV and concentrated solar power technologies. Solar parks, like industrial development zones, offer a variety of incentives, including special tax rates, subsidized land purchase, and government-underwritten labor costs.

2. **Nongovernmental organization (NGOs) and other agency-led.** NGOs and aid agencies have helped build solar markets through programs such as the International Finance Corporation and the World Bank's Lighting Africa, which focuses on providing financial institutions with market information and addressing solar financing gaps in the market.
3. **Emerging-market, multinational enterprise-led.** China is now the world's largest solar panel manufacturer. Several of its emerging solar multinational companies are now key players in the scaling up of solar power in Africa by way of low-priced exports and solar plant development contracts. Solar PV innovations made by these Chinese firms have also lowered the cost of solar PV panels and lanterns.
4. **Avon model**. In East Africa, Sudan, and South Sudan, Solar Sister works to recruit and train women to start their own solar social enterprises and, by way of a network of contacts, to sell and distribute solar products in rural areas.
5. **Pay-as-you-go (PAYG)**. Instead of requiring a lump sum payment for solar systems, PAYG firms sell systems against small installments. If a customer fails to make a payment, the system has a technology that allows the firm to lock its functionality. Approximately 20 different PAYG firms exist and have close to a half-million customers (primarily in East Africa). It is unlikely that this model will dominate the market unless start-ups are able to partner with existing PAYG firms to take advantage of their wide and efficient distribution networks (Bloomberg 2016).

3. Sustainability of solar power

Concerns about the sustainability of solar power primarily have to do with material availability and waste disposal (Chaurey and Kandpal 2010). Solar panel manufacturing must compete with other semiconductor industries for raw materials and resources. Solar PV systems use semiconducting materials to absorb the photons in the sunlight that hit the panel surface. PV cell production also requires many raw materials with low natural reserves. Steinbuks et al. (2015) conducted a study using simulation results of a computable partial equilibrium model to understand how material scarcity and competition from alternatives affect the expansion of solar power in the long run. For example, PV panels compete with the computer chip industry for polysilicon wafers, and with liquid crystal display manufacturers for indium. The study shows that both material scarcity and competition from alternatives will constrain solar power expansion. Steinbuks et al. (2015) also explain that although it is possible to increase the supply of some of the metals used in solar PV production, this would likely increase production costs and result in a larger environmental footprint.

Another sustainability concern has to do with solar PV system prices, which in recent years have declined by as much as 50 percent (Amankwah-Amoah 2015). Many in African rural areas spend less than 20 cents per kWh for solar PV power (Chipman 2011). Some contend that current prices are unsustainable because China is dumping solar PV systems into markets below manufacturing costs. Recently, several leading firms in the solar industry that are not from China have filed for bankruptcy or experienced losses, cutbacks, and/or substantial write-downs (Bazilian et al. 2013).

4. Impacts of solar power

To date, the majority of evidence regarding the impacts of solar power comes primarily from qualitative and quantitative studies focused on solar power users before and after (in some cases only after) they started using solar systems. Although the findings from studies of this type may offer important insights, it is not possible to use them to make causal inferences about solar power impacts.

Chaurey and Kandpal (2010) reviewed and analyzed the literature on the decentralized rural applications of solar PV systems. More recently, Harrison et al. (2016) reviewed available literature and unpublished research data held by SolarAid, an international charity that provides solar lights in remote areas around the world. They note that most of the published literature is limited and many of the studies, including SolarAid's research data, use small sample sizes and rely on self-reported information provided by solar PV system users.

In rural households, the highest end use of energy is for cooking; however, with low energy availability, solar PV systems are unable to make an impact on the types of energy used for this activity (Karekezi and Kithyoma 2002). Wamukonya and Davis (2001) found that households with solar systems could not use them for cooking because of their limited power (50 W). In sub-Saharan Africa, only about 17 percent of the population use clean cook stoves such as those running on solar energy (Kammila et al. 2014). In Tanzania, solar cookers are used on such a small scale that there is very limited information on this solar market segment (Ondraczek 2013).

Regarding the use of solar power for lighting, findings from a SolarAid survey show that households increased the amount of time that they spent lighting their homes from 3.8 to 5 hours per night (Harrison et al. 2016). A study in Ghana found that households that rely on solar PV for lighting instead of kerosene lanterns also benefit in terms of the reduction in indoor air pollution caused by the indoor air smoke and heat from kerosene lanterns (Obeng et al. 2008). The direct benefits of solar PV system's displacement of kerosene range from 15.2 to 21.3 liters/month in Argentina to 12.0 liters/month in Burkina Faso and 5 liters/month in Bolivia. Additionally, the annual emission reduction potential of more than 70 percent of systems exceeds 200kg CO_2 (Chaurey and Kandpal 2010; Kaufman and Duke 2000; Ybema et al. 2000; Kandpal et al. 2003; Posorski et al. 2003).

A study by SolarAid found that rural households in Africa spend about 10 percent of their income on kerosene, torches, or candles for four hours of nighttime lighting. In comparison, households using solar lighting spend just 2 percent of their income on lighting (Harrison et al. 2016). Grimm et al. (2015) in Rwanda found that reduced lighting costs also translated into increased lumen hour consumption per day, with pico-solar household consumption being twice that of comparison households.

Solar power may also be used for income-related activities. Jacobson (2007) in Kenya found that 32 percent of households (out of 76) reported using solar lights for income-generating activities. Additionally, some studies have found that solar lights increased the likelihood of generating more income by enabling businesses to extend their hours of operation (Harrison et al. 2016). However, other studies did not find that their use leads to substantial increases in rural incomes (Martinot et al. 2002; Nieuwenhout et al. 2000).

A recent study in Bangladesh relied on a financing scheme with a subsidy for disseminating SHS units among poor rural households, and estimated impacts by comparing outcomes for SHS adopters and non-adopters. The impact evaluation found that even with the decline of the subsidy over time, SHS demand has experienced impressive growth because technological developments have made it more affordable. Furthermore, the study found that SHS adoption increased evening study time, reduced kerosene consumption, and resulted in health benefits for household members (Samad et al. 2013). A randomized controlled evaluation is currently being carried out in Kenya to estimate the impact of different pricing schemes, payment schedules, and enforcement methods on the adoption of off-grid solar power, as well as the impact of access to electricity on small retail businesses' revenue and profits (Jack and Suri 2013).

5. Uses of solar power

Hospitals, households, and businesses across sub-Saharan Africa are increasingly turning to solar power to reduce dependence on unreliable power grids (Amankwah-Amoah 2015). In Tanzania, solar PV power's main uses include lighting, cell phone charging, and televisions and radios. Recently, solar PV systems have also been used for powering electric equipment in health centers, schools, homes, and missionary centers. Governments, donors, and NGOs such as Solar Now and SolarAid are also increasingly providing solar systems as part of their off-grid rural projects in schools and health centers. There has also been some small-scale commercial use of solar power by small businesses for cell phone charging and music systems (Ondraczek 2013).

According to several sources, solar PV use in Tanzania can be divided into three broad areas (Ondraczek 2013; Karekezi 1994; Hankins 2000; ESDA 2003; Kassenga 2008):

1. **Electricity generation.** Institutions such as health centers and schools are using SHS-powered lighting systems. Health centers are also increasingly using PV-based vaccine refrigerators.
2. **Information and communication.** Tanzania has been improving its communication networks through PV-powered communication systems.
3. **Water pumping.** Some agriculture producers are using PV power to drive water pumps for irrigation.

Our evaluation of MCC's Kigoma solar activity contributes to the literature by examining solar power use among schools, health facilities, village markets, fishers, and households. More specifically, our data provide suggestive evidence on possible solar power impacts on these different types of individuals and institutions across several outcome domains.

D. Organization of the report

This report utilizes data from the interim survey as well as follow-up data collected in 2015 to assess changes in key outputs and outcomes between the targeted and nontargeted groups and over time. Chapter II of this report describes the evaluation questions, data, and design for this evaluation. Chapter III summarizes findings related to the implementation of the Kigoma solar activity, and Chapter IV summarizes findings related to key outcomes. Chapter V concludes, and discusses some key lessons and considerations for future solar PV programs.

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II. EVALUATION DESIGN AND DATA

A. Evaluation questions and domains

The Kigoma solar evaluation was designed to answer questions about the implementation of the program and about outcomes that may have been affected by the program. Specifically, our evaluation questions were:

1. How was the Kigoma solar activity implemented?
2. How did outcomes differ at follow-up and change over time for the targeted group selected to receive the Kigoma solar activity versus the nontargeted group?

We sought to answer the first question by examining several implementation domains: (1) implementation processes and experience with the program, (2) installation of MCA-T-funded solar systems, and (3) service quality of solar systems. To answer the second question, we examined several performance domains: (1) electric and non-electric energy consumption and expenditures, (2) investment and economic activities, (3) human capital accumulation, and (4) economic growth. Individual outcomes assessed within each implementation and performance domain are described in greater detail in Section II.B. We assessed outcomes in these domains primarily by comparing outcomes at two time points among targeted and nontargeted respondents. Our evaluation methods are described in more detail in Section II.C.

B. Data

1. Data collection

Two separate rounds of data were collected for the evaluation of the Kigoma solar activity. For the first round, MCA-T contracted an independent consultant who collected the data in 2013. The program was supposed to be implemented between March 2012 and May 2013, but the first round of data was not collected until July 2013—and about two-thirds of the installations were complete at that time (Busalama 2013). Hence, although we make comparisons between the first and second rounds of data collection (as discussed in further detail in Section II.C), note that the first round (referred to throughout this report as *interim* data collection) does not constitute a true baseline in most cases. However, it does provide baseline information for one component—the hospital refrigerators—because the first round was collected before the hospital refrigerators had been distributed. In addition, in some cases, we made use of retrospective data that were collected at the time of interim data collection to assess changes that occurred after implementation of the Kigoma solar activity.

The Kigoma solar activity targeted installations of solar PV systems at schools, dispensaries, health centers, and village markets in two districts of Kigoma Region. These targeted institutions were to receive free solar PV systems through the activity. The activity also provided support to Savings and Credit Cooperative Organizations (SACCOs) and beach management units (BMUs) from which individual households, businesses, and fishers could purchase systems at a reduced rate. Interim data collection sampled targeted schools, dispensaries, health centers, village markets, businesses within village markets, BMUs, and SACCOs purposively, with priority given to villages with the most solar PV installations to maximize data collection efficiency (Busalama 2013). Individual businesses, households, and fishers were sampled randomly from

SACCOs' and BMUs' lists of people and businesses that purchased systems. For all respondent types, corresponding nontargeted respondents were selected purposively. Nontargeted respondents were selected from distinct geographic areas to minimize the possibility of contamination. No additional efforts were made to select nontargeted respondents to be similar to targeted respondents; as a result these two groups of respondents may differ in significant ways on characteristics that might affect our outcomes of interest. Thus, comparisons made between the outcomes of these groups (as described in greater detail in Section II.C) will not provide rigorous evidence on program impacts. A total of 122 individual-level respondents and 19 group-level respondents completed the interim survey.

Mathematica was contracted by MCC to collect and analyze a second round of data; in turn, we hired Economic Development Initiatives (EDI) to collect the data. The second round of data collection was completed in September 2015. For follow-up data collection, we decided to interview only individual-level respondents and did not re-interview SACCOs, BMUs, or village markets. We successfully re-interviewed 114 of the original 122 individual-level respondents[2]; however, four market businesses (all nontargeted), two SACCO businesses (all targeted), and two households (one each in the targeted and nontargeted groups) could not be located during follow-up data collection. This produced an overall response rate of 93.4 percent among individual-level respondents. The number and type of respondents sampled for the interim and follow-up evaluations are described in Table II.1.

Table II.1. Sample sizes for Kigoma solar surveys

	Interim survey sample size		Follow-up survey sample size	
Respondent type	**Targeted**	**Nontargeted**	**Targeted**	**Nontargeted**
Schools	10	5	10	5
Dispensaries	14	4	14	4
Health centers	6	3	6	3
Businesses in village markets	12	8	12	4
SACCO businesses	16	8	14	8
SACCO households	16	8	15	7
BMU fishers	8	4	8	4
Total individual respondents	**82**	**40**	**79**	**35**
SACCOs	4	0	0	0
BMUs	4	2	0	0
Village markets	4	5	0	0
Total group respondents	**12**	**7**	**0**	**0**

Source: Kigoma solar interim survey (2013) and follow-up survey (2015)

For follow-up data collection, EDI attempted to interview the same person who was interviewed in the interim survey (this was typically the head of each respondent type surveyed, meaning the director of a school or health facility, business owner, head of a household, or so

[2] One of these 114 respondents was located in a community that was targeted for the transmission and distribution (T&D) activity, a key component of MCC's energy sector project.

on). When the same respondent was not available, EDI interviewed another respondent in the facility or household who had sufficient knowledge to respond to the questions.

During the follow-up survey, we learned that none of the 12 fishers surveyed reported ever receiving or using an MCA-T system and, therefore, could not respond to questions about their exposure to the program, use of solar power, or experience with participating in the program. Because targeted fishers were supposed to have been sampled from BMUs' lists of fishers who purchased systems, we expected that 8 of the 12 total sampled fishers should have reported receiving an MCA-T system at some point. The fact that no fishers reported this suggests that there may have been some issue with the way in which fishers were sampled, or that the information available at the time of sampling was incomplete or incorrect.[3] We exclude fishers from some results related to implementation in Chapter III, as noted in those tables.

The distribution of respondents by type was similar between targeted and nontargeted groups at follow-up (Table II.2). For example, 13 percent of targeted respondents and 14 percent of nontargeted respondents were schools. The loss of 8 respondents did produce some imbalance in the makeup of respondent types, however. For example, at follow-up, SACCO businesses composed 18 percent of the targeted sample and 23 percent of the nontargeted sample.

Table II.2. Distribution of respondents by type at follow-up

Type	Targeted	Nontargeted
Schools	13%	14%
Dispensaries	18%	11%
Health centers	8%	9%
Businesses in village markets	15%	11%
SACCO businesses	18%	23%
SACCO households	19%	20%
BMU fishers	10%	11%
Total	100%	100%
Total sample size	79	35

Source: Kigoma solar interim survey (2013) and follow-up survey (2015)

2. Data sources

We utilized data from both interim and follow-up rounds for our analyses. The interim survey also asked respondents to retrospectively report on their energy use and other activities 12

[3] The BMU component of the Kigoma solar activity was originally implemented as a demonstration program, with the goal of spurring fishers' purchase of PV systems for their boats after demonstrating that these systems worked. A former Camco employee said that it is possible that BMUs' lists from which fishers were sampled for this study were lists of those targeted for PV systems, rather than fishers who actually received systems, although the interim report did suggest that they were using their systems (Busalama 2013). We attempted to explore other possible reasons for the fact that no fishers in our sample reported using MCA-T PV systems. Unfortunately, the MCC team was not able to determine where the lists of fishers came from or whether they may have been incorrect. Another possible partial explanation for the findings is that the fishers forgot that they got their solar systems from MCA-T by the time of the follow-up survey. However, only one fisher reported having used a non-MCA-T solar system in that survey. It is also possible that some fishers moved to different boats between the interim and follow-up surveys and that even if their boats at interim had used PV systems at some point in time, their boats at the time of follow-up had not.

months prior to the survey. For the interim report published in 2013, these responses were treated as a retrospective baseline (Busalama 2013). Respondents were also asked questions about their current energy use and activities at the time of the interim survey. For our evaluation, we focused primarily on comparisons of outcomes at follow-up and on changes since the interim results, but we also did a few comparisons using the retrospective baseline. The second round of data collection, conducted by Mathematica and EDI, provided the follow-up results for our evaluation.

In both data collection rounds, the survey administered to participants was designed to assess a range of topics related to the implementation of the Kigoma solar activity and the activity's potential impacts on energy use and facility or household operations. The follow-up survey included some additional questions about the experience of activity participants. In addition to the main component of the survey, which was delivered to all respondents, each respondent type was asked a small set of specific questions to better understand topics related to their operation, such as the number of students that schools had, the number of patients that health facilities served, and the daily revenue of businesses and fishers.

Within each implementation and performance domain, we utilized survey data from both rounds of data collection (when possible) to assess a number of outcomes. These are described in Table II.3. Several outcomes were specific to a subset of respondent types; these are noted below.

Table II.3. Implementation and performance domains and outcomes

Domain	Outcomes
Implementation	
Process & experience	Program knowledge Exposure to marketing campaign Experience with program participation
Installation	Installation of solar systems Use of solar systems
Service quality	Problems encountered with solar systems Repair and maintenance costs Training for repair and maintenance
Performance	
Energy consumption & expenditures	Monthly consumption of electricity and non-electric fuels Monthly expenditures on electricity and non-electric fuels
Investment & economic activities	Operating hours (schools, health facilities, businesses) Staff size (schools, health facilities, businesses) Average daily revenue (businesses, fishers)
Human capital accumulation	Availability of vaccines and vaccine refrigerators (health facilities)
Economic growth	Per capita income (households)

We used our judgment to top code some outcome variables in order to prevent extreme outliers from driving our results. Our purpose in top coding some variables was to remove any observations so extreme that they were likely to be errors, while preserving real observations that happened to be unusually large. For this reason, rather than top coding at a specific percentile, we reviewed extreme values for each outcome variable and made top coding decisions individually. Although we may have eliminated some genuine extreme values from our data, the process helped to produce results that were interpretable, and not driven by a small number of extreme values.[4] For all outcome variables that contained large outliers, we top coded the outliers to the highest non-outlying value before conducting our analyses. In many cases, outliers may have been reasonable responses rather than reporting or data entry errors. For example, two health centers and one dispensary reported very high monthly charcoal use, primarily for boiling water: in the last month, one reported using 32,000 kilograms, and the other two reported 750 and 760 kilograms, respectively. These were all large facilities that had served more than 100 patients in the last week, so it may have been reasonable for the facility to use large amounts of charcoal. However, this usage was extreme in our sample and would have produced an extreme difference in charcoal use at interim between target and nontarget groups, so we top coded these three observations to the next highest, non-outlying observation, which in this case was 360 kilograms. Results based on top-coded outcomes are labeled accordingly throughout this report. We also present results based on the non-top-coded versions of these outcomes in the appendix.

C. Evaluation methods

Our evaluation covered all seven types of potential respondents in both targeted and nontargeted groups. The respondent types are (1) schools, (2) health centers, (3) dispensaries, (4) businesses in village markets, (5) fishers, (6) businesses that received loans from local credit institutions to purchase solar systems, and (7) households that received loans from local credit institutions for solar systems. Because of the small sample sizes and the purposive sampling of the nontargeted group, we cannot estimate impacts rigorously; nevertheless, our findings are helpful for assessing potential impacts of the activity, as described in greater detail below.

To address the first research question, covering implementation, we looked at differences in the implementation outcomes between the targeted and nontargeted groups and changes over time in those outcomes. In particular, we examined differences between the targeted and nontargeted groups in exposure to the marketing campaign conducted under the Kigoma solar activity and in installation and use of MCA-T solar PV systems. We also examined changes in solar PV use between the interim survey and the follow-up survey among all targeted respondents. In addition, we compared the use and service quality of MCA-T and non-MCA-T PV systems at follow-up, comparing all MCA-T users with all non-MCA-T users, regardless of their group assignment. To calculate these comparisons, we used the following regression model:

$$(1) \qquad Y_i = \beta_0 + \beta_1 \text{Group}_i + \alpha_i + \varepsilon_i$$

where Y_i is the outcome of interest for respondent *i*. Depending on the type of comparison being made, $Group_i$ represents a dummy variable identifying whether or not respondent *i* is in the targeted group (1 if targeted, 0 otherwise), whether or not their observation comes from the follow-up survey, or whether or not they are an MCA-T system user. The α_i s are respondent type fixed effects, assumed to be constant regardless of the value of $Group_i$, and ε_i is an

[4] The outcomes that were top coded ranged from the 92nd to the 97th percentile. More details about how top coding was done by variable can be found in the table notes in the appendix.

individual error term. For the purposes of this analysis, we considered health centers and dispensaries to be a single respondent type because they are similar facilities and received all of the same survey questions. The coefficient β_1 is the estimate of the difference of interest (either the difference between the targeted and nontargeted group, the difference between follow-up and interim survey, or the difference between MCA-T and non-MCA-T system users).

Last, we examined the challenges and benefits of participation in the Kigoma solar activity among those who reported using MCA-T systems at follow-up.

To address the second research question, covering outcomes in the performance domains, we compared outcomes between the targeted and nontargeted groups and analyzed how key outcomes changed over time. For most outcomes, this meant looking at change between the interim and follow-up surveys, though for a few outcomes we could also look at changes between the pre-activity retrospective data and the follow-up survey. The methods used to conduct these comparisons were dependent on the types of data available.

For most outcome domains, as mentioned above, we calculated an adjusted difference at follow-up and an adjusted net change. The latter concept can be thought of as the difference between targeted and nontargeted groups at follow-up minus the difference between targeted and nontargeted groups at interim, adjusting for respondent type.[5] We used the following regression model:

$$(2) \qquad Y_{it} = \beta_0 + \beta_1 \text{Targeted}_i + \beta_2 \text{Post}_t + \beta_3 (\text{Targeted}_i * \text{Post}_t) + \alpha_i + \varepsilon_{it}$$

where Y_{it} is the outcome for respondent i at time t, Targeted_i is a dummy variable identifying whether or not respondent i is in the targeted group, Post_t is a dummy variable identifying whether or not the time point is at follow-up, and ε_{it} is an individual, time-specific error term. The coefficient β_1 can be thought of as the adjusted difference in outcomes between the targeted and non-targeted group at the earlier time point. The coefficient β_3 is the adjusted net change. The sum of β_1 and β_3 is the adjusted target-nontarget group difference in outcomes at follow-up. The adjusted target group mean at follow-up is the sum of the unadjusted nontarget group mean at interim plus the three coefficient estimates (β_1, β_2, and β_3). P-values are only presented for comparisons where the total sample size was 30 or greater. For all outcomes with top-coded observations, we note the number of observations that were top coded in the relevant table. We also conducted net change analyses using the original versions of the outcome variables without top-coded observations. These analyses can be found in Appendix A. All analyses for both research questions are done without weights; therefore, the results only generalize to respondents similar to those found in our analyses. For outcomes with retrospective data, we estimated equation (2) but replaced the interim data with the retrospective data. In some cases, we collected

[5] Although this approach is consistent with a standard difference-in-difference analysis, we do not refer to it as such because our approach is not a rigorous estimate of impact, as difference-in-difference analyses are intended to be. Because of the small sample sizes, the purposive sampling of the nontargeted group, and the timing of interim data collection, our results should be considered descriptive.

information during the follow-up survey that was not collected during the first round of data collection. For these questions, we present only differences between the targeted and nontargeted groups at follow-up when addressing research question 2.

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III. ACTIVITY IMPLEMENTATION

In this chapter, we present evidence related to the implementation of the Kigoma solar activity in our three implementation domains: (1) implementation processes and experience with the activity, (2) installation of MCA-T-funded solar systems, and (3) service quality of solar systems.

A. Implementation processes

The Kigoma solar activity was designed to provide metered PV systems for certain public institutions and village markets, solar-powered night-fishing systems for fishers, and commercially sold PV systems for homes and small businesses. The activity targeted specific numbers of schools, health facilities, village markets, and BMUs to receive PV systems, but did not set specific targets for the number of market businesses to make use of village market systems or the number of fishers, households, or individual businesses to purchase systems through SACCOs. The different systems made available to individuals and institutions are described in Table III.1.

Table III.1. Key components of the Kigoma solar activity

Respondent type	PV system and purpose	PV system capacity	Number targeted to receive systems
1. Schools	Metered AC electrical system for lighting classrooms and offices, computer/TV use, and cell phone charging	3 kWh per day	45 schools
2. Dispensaries; 3. Health centers	Metered AC electrical system for lighting and media services, and cell phone charging; Vaccine refrigerator system for storing BCG, measles, and polio vaccines, as well as other vaccines as needed	1 kWh per day	116 dispensaries; 14 health centers
4. Fishers	Encouraged to purchase systems through BMUs. BMUs distributed unmetered DC electrical systems consisting of a solar PV array installed at the fisher's home, lamps installed on the boat, and a portable battery charger	0.45 kWh per day (powering 5 LED lamps for 9 hours)	38 BMUs
5. Businesses in village markets	Utilized power from village market systems. Village markets received metered AC electrical system with submeters for different users to provide general lighting in the market and lighting for individual businesses.	2.6 kWh per day	25 village markets
6. SACCO businesses; 7. SACCO households	Encouraged to purchase unmetered Pico Solar PV systems and Solar Home Systems through SACCOs that could be used for a variety of home and small business needs	20–50 Watt peak	N/A

Source: Kigoma solar baseline and interim performance evaluation report (Busalama 2013)

Other supporting components of the activity included organized marketing of the solar systems and their benefits; training of installers, vendors, and end users; and maintenance and after-sale services. Marketing addressed knowledge gaps on PV technology, concerns about quality issues, cost, financing, distribution, and operations and maintenance of the PV systems. Trainings included providing information to key audiences on system capacity and how systems should be installed and used. After-sale services included ongoing maintenance services for end users. Different respondent types were offered different kinds of PV systems with different capacities.

B. Activity knowledge

Information about the Kigoma solar activity was disseminated through a multi-component marketing campaign led by Camco Tanzania. In addition to large kickoff events such as a soccer game and public speeches, Camco organized ongoing marketing activities to expand public awareness of the activity in the two targeted districts. These activities included conducting public awareness meetings and demonstrations, holding performances by tribal dancers and local entertainers to deliver information about the project, distributing flyers, and putting up billboards. The marketing campaign also included a short message service (SMS) component whereby community members were invited to send text messages to a central phone number in order to receive more information about the activity.

In the follow-up survey, both targeted and nontargeted respondents reported being exposed to activity marketing at high levels, though the level of exposure varied widely between targeted and nontargeted respondents (Table III.2). Specifically, adjusted for respondent type, 66 percent of targeted and 45 percent of nontargeted respondents reported hearing about the activity through public meetings; this 21-point difference was significant at the 5 percent level. Seeing flyers or billboards was also common: 61 percent of targeted and 55 percent of nontargeted respondents reported seeing flyers, and 55 percent of targeted and 58 percent of nontargeted respondents reported seeing billboards. Performances and demonstrations were not very common and were seen more often by nontargeted than by targeted respondents: 2 percent of targeted and 6 percent of nontargeted respondents reported seeing performances, and 4 percent of targeted and 10 percent of nontargeted respondents reported seeing demonstrations. Nine percent of both targeted and nontargeted respondents reported being exposed to four different marketing components; no respondents reported being exposed to more than four.

No respondents in either group reported hearing about the activity through SMS messaging, suggesting that the SMS component of the campaign was less successful than other components.[6] It is also possible that the question was misunderstood by respondents: the Swahili term used for "SMS messages" in the survey instrument was one of at least two commonly used

[6] During pilot testing for the survey, two respondents reported hearing about the activity through SMS messages. This suggests that although the SMS message component may have been deployed as planned, it reached fewer people than other marketing components. In addition, a former Camco employee informed us that SMS outreach was targeted specifically to mobile phone users who were using mobile money with a select set of vendors in study areas. Our small sample may not have captured this particular population.

terms[7]; the term used in the instrument may be less commonly used in the communities covered by this survey.[8]

Table III.2. Exposure to marketing campaign components reported at follow-up (percentages)

Campaign component	Adjusted target mean	Nontarget mean	Adjusted difference
Entertainment	2.2%	6.5%	-4.3
Public meetings	66.3%	45.2%	21.1**
Flyers	60.7%	54.8%	5.9
Billboards	55.0%	58.1%	-3.1
Demonstrations	4.4%	9.7%	-5.2
SMS	0.0%	0.0%	0.0
Advertisements	36.9%	54.8%	-17.9*
Other	5.9%	9.7%	-3.8
Exposure to four activity components [a]	9.6%	9.7%	-0.1

Source: Kigoma solar follow-up survey (2015)

Notes: Targeted sample size = 71, Nontargeted sample size = 31. Sample sizes for some variables may be smaller due to nonresponse. Adjusted difference results are based on regressions that control for respondent type. See section II.C for details. Adjusted target mean is the nontarget mean plus the adjusted difference.

*/**/*** Estimate is significantly different from zero at the .10/.05/.01 level using a two-tailed test.

Table excludes fishers.

[a] No respondents were exposed to more than four activity components.

C. Installation and use of MCA-T PV systems

In order to assess how well the Kigoma solar activity had been implemented, we examined how many respondents had received PV systems provided by MCA-T. Based on data from the follow-up survey, all targeted schools, health centers, and dispensaries received MCA-T-sponsored PV systems through the Kigoma solar activity as planned (Table III.3). All of these health centers and dispensaries and 80 percent of the schools were still using these systems at the time of the survey. All targeted health facilities also received a solar-powered vaccine refrigerator. Almost all targeted market businesses and households received the PV systems (92 and 93 percent, respectively), but only 67 percent of market businesses and 53 percent of households were still using their systems. Only 71 percent of targeted SACCO businesses received systems, suggesting that the lists of participating businesses obtained from SACCOs for sampling purposes may not have been completely accurate or that the lists were made before businesses had fully committed to purchasing systems.

[7] The term used in the survey instrument was "Ujumbe Mfupi"; the other commonly used term is "Mesenji."

[8] The marketing report states that over the course of the marketing campaign, they sent several SMS messages to more than 10,000 phone numbers each, and received more than 790 replies to register to receive more messages or to request information about vendors or technicians (Camco 2012). The marketing report provided the phone numbers of 101 SMS users who responded with SMS messages. We compared these phone numbers to the phone numbers of our survey respondents and found no matches. This helps to corroborate the survey responses, though it is possible that some of our survey respondents did receive SMS messages but did not reply to them.

In addition to most targeted respondents, some nontargeted respondents also reported receiving MCA-T PV systems. Twenty-five percent of nontargeted dispensaries and SACCO businesses and 100 percent of nontargeted market businesses reported receiving them. None of the nontargeted dispensaries were using their systems at the time of the survey. Thirteen percent of nontargeted SACCO businesses and 100 percent of market businesses were using their systems. No nontargeted respondents were expected to have received MCA-T systems. The fact that several nontargeted respondents reported doing so was unexpected and suggests that implementation plans may have changed, that the lists of nontargeted respondents may have been inaccurate, or that the survey questions were misunderstood by these respondents.

Although the interim survey asked respondents about their use of solar PV systems generally, it did not ask respondents to distinguish between systems provided by MCA-T or by others. For this reason, we were unable to assess any possible changes in the use of MCA-T systems between the interim and follow-up surveys.

Table III.3. Installation of MCA-T solar systems

	Received MCA-T PV system			Currently using MCA-T PV system		
Respondent type	Target	Nontarget	Difference	Target	Nontarget	Difference
Schools	100%	0%	100***	80%	0%	80***
Health centers	100%	0%	100***	100%	0%	100***
Health centers – vaccine refrigerators	100%	0%	100***	83%	0%	83***
Dispensaries	100%	25%	75***	100%	0%	100***
Dispensaries – vaccine refrigerators	100%	0%	100***	92%	0%	92***
Village market businesses	92%	100%	-8	67%	100%	-33
SACCO businesses	71%	25%	46**	57%	13%	45**
SACCO households	93%	0%	93***	53%	0%	53**

Source: Kigoma solar follow-up survey (2015)

Notes: Targeted sample size = 71, Nontargeted sample size = 31. Sample sizes for some variables may be smaller due to nonresponse.

*/**/*** Estimate is significantly different from zero at the .10/.05/.01 level using a two-tailed test.

Table excludes fishers.

We examined the use of solar PV systems among targeted respondents at interim and follow-up and found statistically significant increases in the number of hours that targeted respondents used solar PV systems for key activities. We examined changes in the use of PV systems by comparing targeted respondents' total use of solar PV systems at interim and follow-up (Table III.4). We found statistically significant increases in solar PV use for daytime lighting (1.4 hours), TV use (0.4 hours), and computer use (0.3 hours). We obtained the total use of solar PV systems for all purposes by adding the number of hours used for each individual purpose. This total, which could represent simultaneous use of PV systems for multiple activities, was 12.2 hours at interim and 13.6 hours at follow-up, resulting in a difference of 1.4 hours that was not statistically significant. Respondents were also asked about the average use of their PV systems in a 24-hour period. Because this measure does not count simultaneous use for multiple activities, we expected it to be smaller than the total use of PV systems for all activities. The difference in average PV use in a 24-hour period was not statistically significant, with 12 hours at interim and 14 hours at follow-up.

Although overall usage of solar PV increased somewhat over time, the proportion of MCA-T system users who felt that their systems met their energy needs fell over this same period. At follow-up, only 31 percent of current MCA-T system users reported that their solar PV systems met their energy needs. Among these same 52 respondents, 42 percent reported that their solar PV systems met their energy needs at interim. This suggests that needs and expectations for energy availability and usage may have increased over time as users began relying more on their systems.

Table III.4. Average daily hours of use of any solar PV system at the time of the interim and follow-up surveys, among targeted respondents

Purpose	Adjusted follow-up mean	Interim mean	Adjusted difference
Use in the last 24 hours			
Light during the day	2.25	0.83	1.42*
Light at night	7.90	7.10	0.80
Operating a radio	0.85	1.03	-0.18
Operating a television	0.46	0.10	0.37**
Operating a computer	0.39	0.04	0.34**
Operating a fan	0.02	0.00	0.02
After-hours study programs	0.99	2.04	-1.05**
Free cell phone charging	2.83	3.70	-0.87
Cell phone charging for a fee	1.14	1.46	-0.32
Cinema business for a fee	0.00	0.00	0.00
Other use	1.15	0.00	1.15
All uses	17.89	16.06	1.83**
Average use in 24 hours	13.61	12.18	1.44
Solar system met energy needs [a]	0.31	0.42	-0.12

Source: Kigoma solar interim survey (2013) and follow-up survey (2015)

Notes: Sample size = 70. Sample sizes for some variables may be smaller due to nonresponse. Adjusted difference results are based on regressions that control for respondent type. See Section II.C for details. Adjusted follow-up mean is the Interim mean plus the adjusted difference. Table excludes fishers.

*/**/*** Estimate is significantly different from zero at the .10/.05/.01 level using a two-tailed test.

[a] Assessed only among current users of MCA-T systems at follow-up (sample size = 52).

At the time of the follow-up survey, 61 percent of all respondents reported using a solar PV system (Table III.5). Forty-two percent of all respondents were using only an MCA-T system (54 percent of the targeted group and 14 percent of the nontargeted group). Eleven percent of all respondents were using only a system provided by someone other than MCA-T (4 percent of the targeted group and 29 percent of the nontargeted group), and 8 percent of respondents were using both (11 percent of the targeted group and 0 percent of the nontargeted group).

Table III.5. Use of MCA-T and non-MCA-T Solar PV systems

Type of system	Target group users	Nontarget group users	All users
MCA-T system only (%)	54	14	42
Non-MCA-T system only (%)	4	29	11
Both MCA-T and non-MCA-T systems (%)	11	0	8
Any system (%)	70	43	61
Total sample size (N)	79	35	114

Source: Kigoma solar follow-up survey (2015), includes fishers.

Usage patterns for MCA-T and non-MCA-T users look similar overall, with only a few statistically significant differences (Table III.6). MCA-T users reported using their systems for an average of 0.8 hours per day to use computers; non-MCA-T users reported using their systems for this purpose for an average of 0.2 hours per day, producing a small difference that was significant at the 10 percent level. Additionally, MCA-T users reported using their systems for an average of 4 hours in a 24-hour period for free cell phone charging, whereas non-MCA-T users reported using their systems for an average of 2 hours for this purpose; this difference is statistically significant at the 5 percent level. Although it was hoped that respondents would use their solar PV systems for some income-generating activities, neither MCA-T nor non-MCA-T systems were used extensively for activities such as cell phone-charging businesses, cinema businesses, or other fee-based activities. One household reported using the PV system for income generation (cell phone-charging business); other than that, only market businesses and SACCO businesses reported using their systems for any income generation. The total use of solar PV systems in the last 24 hours, obtained by adding the amount of time spent on all individual uses, was greater for users of MCA-T systems than for users of non-MCA-T systems (20 hours compared with 16 hours), but this difference was not statistically significant. The difference in MCA-T and non-MCA-T users' reports of the total number of hours they used their systems in the last 24 hours, which does not include simultaneous usage for multiple activities, is similar: MCA-T users reported 17 hours of use in a 24-hour period and non-MCA-T users reported 14 hours of use, a difference that was statistically significant at the 10 percent level.

Taken together, these findings suggest that use of solar PV systems has increased slightly over time, with few differences in the way that systems provided through the Kigoma solar activity and systems obtained elsewhere are used.

Table III.6. Average hours of use of MCA-T and non-MCA-T solar systems in last 24 hours at follow-up, among current system users

Purpose	Adjusted MCA-T mean	Non-MCA-T mean	Adjusted difference
Use in the last 24 hours			
Light during the day	3.13	1.71	1.41
Light at night	10.08	8.67	1.42
Operating a radio	0.18	0.57	-0.39
Operating a television	0.20	0.81	-0.61
Operating a computer	0.83	0.24	0.60*
Operating a fan	0.03	0.00	0.03
After-hours study programs	1.35	1.81	-0.46
Free cell phone charging	3.50	1.86	1.65**
Cell phone charging for a fee	0.15	0.57	-0.42
Cinema business for a fee	0.00	0.00	0.00
Other free service	1.07	0.19	0.88
Other fee-based service	0.00	0.00	0.00
Other use	1.07	0.19	0.88
All uses	20.54	16.43	4.11
Average use in 24 hours	17.23	13.95	3.28*

Source: Kigoma solar follow-up survey (2015)

Notes: MCA-T sample size = 57, non-MCA-T sample size = 22. The 9 respondents using both an MCA-T and a non-MCA-T system are counted in both sample sizes. Sample sizes for some variables may be smaller due to nonresponse. Adjusted difference results based on regressions that control for respondent type. See Section II.C for details. Adjusted MCA-T mean is the Non-MCA-T mean plus the adjusted difference.

*/**/*** Estimate is significantly different from zero at the .10/.05/.01 level using a two-tailed test.

D. Service quality of solar PV systems

At follow-up, users of MCA-T systems were less likely than users of non-MCA-T systems to report experiencing problems with their systems (Table III.7). For example, 10 percent of MCA-T system users reported that their systems failed prematurely or did not operate at all in the last week, compared with 32 percent of non-MCA-T system users; the difference of 23 percentage points is statistically significant at the 10 percent level. Overall, 22 percent of MCA-T system users reported having any failures in the last week, compared with 43 percent of non-MCA-T users, though this difference was not statistically significant.

Only a small number of MCA-T users and non-MCA-T users reported conducting any repairs or maintenance on their systems (16 percent of MCA-T users and 19 percent of non-MCA-T users; the difference is not statistically significant). When repairs were conducted, they could be costly: among those who conducted repairs, the total cost of all repairs was an average of 115,096 Tanzanian shillings (TZS) for MCA-T users and 168,250 TZS for non-MCA-T users. Although recipients of MCA-T systems were supposed to receive training for repair and maintenance of their systems, only 22 percent of MCA-T users reported receiving any such training. This was still greater than the percentage of non-MCA-T users who reported receiving training for their systems (9 percent), though the difference was not statistically significant. It is possible that the training that MCA-T users did receive helped to minimize the number of repairs they needed to conduct and the cost they paid for repairs: differences in the cost of repairs were fairly large, though they were not statistically significant due to small sample sizes.

Table III.7. Service quality of MCA-T and non-MCA-T solar systems

Service quality issue	Adjusted MCA-T mean	Non-MCA-T mean	Adjusted difference
System failed to provide power at any time in last week	16.5%	38.1%	-21.6
System failed to enable devices to function properly at any time in last week	16.9%	38.1%	-21.2
System failed prematurely or was not able to operate at all in last week	10.2%	33.3%	-23.1*
Failed to receive technical support services when needed	14.8%	28.6%	-13.8
Any failures in last week	22.2%	42.9%	-20.7
Total number of failures in last week	3.00	3.95	-0.95
Ever conducted any repairs or maintenance	15.7%	19.0%	-3.3
Total cost of repairs (among all respondents; TZS)	24,742	32,048	-7,305
Total cost of repairs (among those who did any repairs; TZS)[a]	115,096	168,250	-53,154
Ever received training for repair and maintenance of PV system	22.1%	9.5%	12.6

Source: Kigoma solar follow-up survey (2015)

Notes: MCA-T sample size = 57, non-MCA-T sample size = 22. The 9 respondents using both an MCA-T and a non-MCA-T system are counted in both sample sizes. Sample sizes for some variables may be smaller due to nonresponse. Adjusted difference results are based on regressions that control for respondent type. See Section II.C for details. Adjusted MCA-T mean is the Non-MCA-T mean plus the adjusted difference.

/**/** Estimate is significantly different from zero at the .10/.05/.01 level using a two-tailed test.

[a] No significance testing conducted due to small sample size (N = 12).

E. Experience with activity participation

Targeted respondents who reported currently using their MCA-T systems were asked about the benefits and challenges associated with participating in the Kigoma solar activity (Table III.8). The most commonly reported benefits to activity participation were availability of light (reported by 98 percent of participants), being able to charge phones (63 percent), and increased security (58 percent). The benefit of increased security is consistent with findings from the rigorous impact evaluation of grid electricity in Tanzania, which found that extending the availability of electrical lines increased community members' perceived safety at night (Chaplin et al. 2017). The most commonly reported challenges were cleaning the system (reported by 46 percent of participants), insufficient battery capacity (29 percent), and problems with socket extensions (21 percent).

Table III.8. Experience with activity participation

	Percent
Benefits	
Light available at night	98%
Able to recharge phones for free/fee	63%
Security	58%
Able to work at night	27%
Able to provide improved services	25%
Able to recharge other appliances	21%
Able to attract employees	10%
Internet availability	4%
Other benefits	6%
Challenges	
Keeping panels clean	46%
Insufficient battery capacity	29%
Problems with socket extensions	21%
Problems with wires/circuit breakers	12%
Theft/vandalism	4%
Other challenges	4%
No challenges	17%

Source: Kigoma solar follow-up survey (2015)

Notes: Sample size = 52.

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IV. OUTCOMES

In this chapter, we present suggestive evidence regarding the relationship between the Kigoma solar activity and outcomes related to (1) energy use, (2) investment and economic activities, (3) human capital accumulation, and (4) economic growth. We also look at outcomes specific to each respondent type. For each outcome, we show key components of the net change analysis: the adjusted mean in the targeted group at follow-up, the adjusted difference between the targeted and nontargeted groups at follow-up, and the adjusted net change. Additional components of the net change analysis can be found in the supplementary tables in Appendix A.

A. Energy use: all respondents

1. Electricity sources and consumption

The Kigoma solar activity was designed to improve electricity coverage and consumption of electricity. We begin by looking at electricity use among targeted and nontargeted respondents. Table IV.1 presents the percentage of respondents reporting currently using different electricity sources. Solar PV use was common at follow-up, with 89 percent of the targeted group and 61 percent of the nontargeted group reporting that they currently used a PV system. This produced a large difference of 27 percentage points at follow-up, which was significant at the 1 percent level.[9] Retrospective data was obtained on this variable, and based on those data we estimate that about 25 percent of the targeted group already had solar power at baseline, compared with about 13 percent of the nontargeted group. This could reflect a true lack of baseline equivalence, or it could represent recall bias, because solar power users at interim might mistakenly believe that they have been using solar power for a longer time. The change in the proportion of respondents using solar power between the retrospective baseline and follow-up was larger for the targeted group than for the nontargeted group, as expected, but was not statistically significant (Appendix Table A.1). However, most of the change in the proportion of respondents using solar power for the targeted group occurred between the retrospective baseline and interim. Since the interim survey, the nontargeted group has started to catch up with the targeted group, as shown by the negative net change estimate in the first row of Table VI.1.

Use of generators and grid electricity was fairly low among both targeted and nontargeted respondents and was similar among the two groups. The use of dry cell batteries was more common: 36 percent of the targeted group and 48 percent of the nontargeted group reported using batteries at follow-up, resulting in a large but statistically insignificant difference of 12 percentage points at follow-up. In both groups, battery use was more common at interim; at that time, 73 percent of the targeted group and 81 percent of the nontargeted group reported using batteries (Table A.2). Although these findings are not statistically significant, they suggest that the use of batteries fell over time in both groups.

We also assessed the average hours of electricity use per month for different electricity sources, all of which were used primarily for lighting. Monthly use of solar PV systems was quite common, with targeted respondents averaging 397 hours of use and nontargeted

[9] These numbers differ from the descriptive, unadjusted results Table III.5 because regression-adjusted estimates are reported here and throughout Chapter IV.

respondents averaging 174, a large difference of 223 hours that was significant at the 1 percent level. The retrospective data suggest relatively little difference in hours of use of PV systems before the activity was implemented—49 hours per month for the nontargeted group and 86 for the targeted group, resulting in a net change of 154 hours that was statistically significant at the 1 percent level (Table A.1).

Table IV.1. Electricity source and average monthly use

Outcome	Sample size	Adjusted target mean at follow-up	Adjusted target–nontarget difference at follow-up	Adjusted net change [a]
Currently using electricity source (fraction)				
Solar PV systems	102	0.89	0.27***	-0.38***
Generator	102	0.11	0.01	0.06
Electric grid	102	0.02	-0.05	-0.05
Dry cell battery	102	0.36	-0.12	-0.04
Car/motorcycle battery	102	0.06	0.03	0.05
Average monthly electricity use (in hours)				
Solar electricity	102	397	223***	-13
Electricity from generators	102	13	0	4
Grid electricity	102	2	-7	-8
Dry cell battery	102	45	-4	35
Car/motorcycle battery	102	14	2	5

Source: Kigoma solar interim survey (2013) and follow-up survey (2015)

Notes: */**/***Estimate is statistically different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

The average monthly hours of electricity use includes the zero hours for non-users. Results are based on regressions that control for respondent type. See Section II.C and Table A.2 for details.

[a] Adjusted net change refers to the differential in the differences between target and nontarget outcomes at the time of interim and follow-up data collection, controlling for respondent type.

While hours of PV electricity use increased dramatically over time for the targeted group, based on the retrospective baseline findings, it appears that most of this occurred by the time of the interim report. In contrast, hours continued to increase after the interim report for the nontargeted group. More precisely, the hours of PV use grew substantially in the nontargeted group, from 96 hours at interim to 171 at follow-up, and grew much less in the targeted group, from 311 hours at interim to 359 at follow-up (Appendix Table A.2). This produced a relatively small and statistically insignificant net decrease of 27 hours. This is consistent with our findings on the proportion of respondents using solar PV systems, which suggests that changes in use between interim and follow-up were minimal among the targeted group but that use increased dramatically among the nontargeted group. The relatively unchanged use of solar PV systems among the targeted group could be explained by the fact that at interim, almost all targeted respondents already had solar PV systems installed. In contrast, solar PV use increased among nontargeted respondents, which might reflect the rapid growth experienced by Tanzania's solar PV market these past years. The consumer market for solar PV in Tanzania grew from an installed capacity of 300 kilowatt peak in the late 1990s to about 1.2 MWp in 2003 and to more than 5 MWp in 2012 (Hansen et al. 2014; Ondraczek 2013).

We did not find any notable changes in generator use. Consistent with our finding that very few respondents were connected to grid electricity, we found that use of grid electricity was very low compared to other alternative electricity sources. At follow-up, dry cell battery monthly use by targeted respondents averaged 51 hours, whereas grid electricity use averaged only 2 hours among targeted respondents. This finding is not surprising given the limited availability of grid electricity in the area and the very small number of respondents using grid electricity; the average number of hours of grid electricity consumed includes zeros for all non-users. The monthly use of car/motorcycle batteries was also low, with both targeted and nontargeted respondents averaging 12 hours of use.

Together, these findings suggest that the Kigoma solar activity corresponded with a widespread increase in use of solar PV systems among the targeted group and large increases in solar PV use among the nontargeted group, but with no clear changes in the use of other sources of electricity.

2. Electricity expenditures

Respondents who used specific electricity sources were asked to report costs associated with each source. In the case of devices such as generators and solar PV systems, respondents were asked to report the cost of these devices in the market. In the case of grid electricity and batteries, respondents were asked to report their monthly expenditures. For all electricity sources, respondents were coded as spending 0 TZS if they reported not using the source. We found a statistically significant difference at follow-up for solar PV expenditures, with targeted respondents reporting higher expenditures on average. This result may be at least in part because solar PV use was a lot lower among nontargeted respondents. In addition, there was a large (though statistically insignificant) net decrease of 78,540 TZS in the total cost of solar PV systems. Both targeted and nontargeted respondents reported lower solar costs at follow-up than at interim (Appendix Table A.3). This finding suggests a downward trend in the cost of solar PV, which is consistent with what we see in the literature. There were no statistically significant differences at follow-up or net changes between targeted and nontargeted respondents in monthly expenditures on grid electricity and dry cell batteries.

Table IV.2. Electricity expenditures (TZS)

Outcome	Sample size	Adjusted target mean at follow-up	Adjusted target–nontarget difference at follow-up	Adjusted net change [a]
Total cost to purchase devices				
Generators [b]	96	18,505	2,635	-11,061
Solar PV systems [c]	56	179,049	69,195***	-78,540
Monthly expenditure				
Grid electricity	102	535	-3,981	-4,094
Dry cell batteries	96	987	-340	-142

Source: Kigoma solar interim survey (2013) and follow-up survey (2015)

Notes: */**/***Estimate is statistically different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Results are based on regressions that control for respondent type. See Section II.C and Table A.3 for details.

[a] Adjusted Net change refers to the differential in the differences between target and nontarget outcomes at the time of interim and follow-up data collection, adjusted for respondent type.

[b] Follow-up observations top coded at the 97th percentile; three observations top coded.

[c] Interim observations top coded at the 96th percentile; three observations top coded.

3. Non-electric energy consumption

Use of non-electric energy sources varied significantly. For example, although about half of respondents reported using kerosene at interim and about a quarter used kerosene at follow-up, very few reported using liquefied petroleum gas (LPG) at any point (only 3 percent of targeted and 14 percent of nontargeted respondents at follow-up). Charcoal and firewood were the most commonly used solid fuels. Animal dung, straw, and tree leaves were used rarely or not at all. For more details on the use of non-electric energy sources, see Appendix Table A.4.

Targeted respondents used less liquid fuel than nontargeted respondents at follow-up (Table IV.3). Specifically, targeted respondents reported using 1.07 liters, and nontargeted respondents reported using 6.77 liters at follow-up, and this difference was statistically significant at the 1 percent level. The difference appears to be driven primarily by LPG fuel. We also see evidence of a larger drop in LPG use between the interim and follow-up surveys for the targeted group than for the nontargeted group, though that net change is statistically significant only at the 10 percent level. Similar results hold when we compare the follow-up data to the retrospective data (Appendix Table A.1).

The results for kerosene are somewhat different. Targeted respondents reported using 0.74 liters and nontargeted respondents reported using 1.52 liters of kerosene at follow-up. This difference is not statistically significant. However, we did see lower use of kerosene by the targeted group than the nontargeted group in both the retrospective baseline and the interim survey. These findings are consistent with the fact that the targeted group was already using more solar power than the nontargeted group by the time of the retrospective baseline data, and the nontargeted group greatly increased their use of solar power since the interim survey. The low use of kerosene by the targeted group in the retrospective and interim data matters because it means that they had less room to reduce kerosene use than the nontargeted group. Consequently, it is perhaps not surprising that we actually see larger drops in the use of kerosene in the nontargeted group than in the targeted group between the interim and follow-up surveys, which results in positive net change (Table IV.3). A similar result holds when we compare the retrospective and follow-up data (Appendix Table A.1).

The fact that both kerosene and LPG use were lower in the targeted group than in the nontargeted group at both interim and follow-up suggests that the Kigoma solar activity may have succeeded in reducing the amount of liquid fuel used by targeted respondents. The fact that liquid fuel use continued to decrease between the interim and follow-up surveys for the nontargeted group, during a time when their use of solar power increased, further supports the hypothesis that increased use of solar power is associated with decreased use of liquid fuel. Liquid fuel was used primarily for providing light and powering electrical appliances; PV systems were designed to perform some of these same functions and thus could have helped to reduce targeted respondents' reliance on liquid fuel.

Differences in candle use between groups and over time were small and not statistically significant. However, the pattern of small candle use in particular is consistent with growing PV use in the targeted group. Candle use decreased in the targeted group, from 3.95 candles per month at interim to 0.11 candles per month at follow-up (Table IV.3). Small candles were reportedly used primarily to provide light. The fact that availability of light was the most commonly reported benefit of PV systems among MCA-T system users suggests that PV systems may have been replacing small candles as a source of light in the targeted group.

There were no statistically significant differences in the use of other solid fuels at either time point, which is consistent with the fact that PV systems were not designed to serve the same purposes that solid fuel serves, such as cooking and heating. A large net decrease of 29.58 kilograms was observed for firewood, but this difference was not statistically significant and is driven primarily by a large increase in firewood consumption in the nontargeted group, from 38.73 kilograms at interim to 100.81 kilograms at follow-up. Differences in the use of animal dung, straw, tree leaves, and charcoal were small and not statistically significant.

Together, our findings on non-electric energy consumption suggest that the Kigoma solar activity may have contributed to decreases in liquid fuel use among targeted respondents, but was not associated with changes in solid fuel use. These findings are consistent with the fact that the PV systems distributed through the Kigoma solar activity were designed to provide lighting and power appliances—the primary purposes that liquid fuels serve—but were not designed to replace the solid fuels required for activities such as cooking or heating.

Table IV.3. Monthly non-electric energy consumption

Outcome	Sample size	Adjusted target mean at follow-up	Adjusted target-nontarget difference at follow-up	Adjusted net change [a]
Kerosene (liter)	102	0.74	-0.78	0.89
LPG (liter)	102	0.33	-4.92***	-4.25*
Liquid fuels (liter) [b]	**102**	**1.07**	**-5.70*** **	**-3.35**
Small candle (counts)	102	0.11	0.11	-3.63
Medium candle (counts)	102	0.50	-3.02	-2.75
Large candle (counts)	102	0.09	0.09	-0.62
Firewood [c] (kg)	102	69.33	-31.47	-29.58
Animal dung (kg)	102	0	0	0
Straw (kg)	102	0	0	0
Tree leaves (kg)	102	0.01	0.01	0.16
Charcoal [d] (kg)	102	18.73	-6.54	-13.51
Solid fuels(kg) [e]	**102**	**88.14**	**-38.30**	**-43.44**

Source: Kigoma solar interim survey (2013) and follow-up survey (2015).

Notes: */**/***Estimate is statistically different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Results are based on regressions that control for respondent type. See Section II.C and Table A.4 for details.

[a] Adjusted net change refers to the differential in the differences between target and nontarget outcomes at the time of interim and follow-up data collection, controlling for respondent type.

b "Liquid fuels" is the sum of kerosene and LPG.

c Interim and follow-up observations top coded at the 96th percentile; four observations top coded.

d Interim observations top coded at the 97th percentile; three observations top coded.

e "Solid fuels" is the sum of all solid fuels, from small candles to through charcoal, and includes firewood and charcoal top coded as described above.

4. Non-electric energy expenditures

As with electric energy sources, respondents who reported using any non-electric energy sources were asked to report the cost per unit of these fuels in the market where they purchase them. We used this information to calculate total monthly expenditures on non-electric energy sources among respondents who reported using those sources. Respondents who reported not using a particular source were assumed to have spent 0 TZS on that source; respondents who reported using a source but did not report its cost in the market were considered to have missing data on expenditures and were not included in the analyses for that source. Differences in expenditures are consistent with the differences in consumption reported above (Table IV.4). The targeted group spent 2,847 TZS less than the nontargeted group on kerosene at follow-up, but this difference was not statistically significant. Together with a larger difference in kerosene expenditures at interim, these resulted in a net increase of 815 TZS, which was not statistically significant. No LPG users reported the cost of LPG in the market, so we were unable to calculate monthly expenditures on LPG.

Table IV.4. Average monthly non-electric energy expenditures

Outcome	Sample size	Adjusted target mean at follow-up	Adjusted target-nontarget difference at follow-up	Adjusted net change [a]
Kerosene (L)	95	1,329	-2,847	815
LPG (L)	83	0	0	0
Small candle	102	11	11	-349
Medium candle	101	149	-896	-807
Large candle	101	50	44	-428
Firewood [b]	80	4,684	-15,210**	-14,856**
Animal dung	102	0	0	0
Straw	100	0	0	0
Tree leaves	97	1	1	35
Charcoal [c]	96	4,694	-3,698*	-5,118
Solid fuels(kg) [d]	**74**	**9,230**	**-19,680*** **	**-20,551*** **
All non-electric energy sources)[e]	**57**	**11,709**	**-22,272*** **	**-23,921*** **

Source: Kigoma solar interim survey (2013) and follow-up survey (2015).

Notes: */**/***Estimate is statistically different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Results are based on regressions that control for respondent type. See Section II.C and Table A.5 for details.

[a] Adjusted net change refers to the differential in the differences between target and nontarget outcomes at the time of interim and follow-up data collection, controlling for respondent type.

[b] Interim and follow-up consumption observations top coded at the 96th percentile; four observations top coded.

[c] Interim consumption observations top coded at the 97th percentile; three observations top coded.

[d] “Solid fuels” is the sum of all solid fuels, from small candles to through charcoal, and includes firewood and charcoal consumption top coded as described above.

[e] “All non-electric energy sources” is the sum of all energy sources in the table, and includes kerosene, firewood, and charcoal consumption top coded as described above.

Expenditures on firewood were lower at follow-up among the targeted group than the non-targeted group. This is consistent with our findings on firewood use, though the results on expenditures are statistically significant, unlike the results on use. The difference in firewood expenditures was small and statistically insignificant at interim. The difference at follow-up was large, at -15,210 TZS, and was statistically significant at the 5 percent level. This resulted in a statistically significant net decrease of 14,856 TZS. This finding drives the two large net decreases of 20,551 TZS in all solid fuel expenditures and 23,921 TZS in all non-electric energy sources expenditures, which are both significant at the 1 percent level. Thus, being targeted for this intervention was associated with lower expenditures on solid fuel at follow-up and a larger decrease from the interim, relative to the not targeted group.

B. Investment, economic activities, and human capital accumulation

The Kigoma solar activity was designed to help targeted respondents expand their investments, economic activities, and human capital accumulation. We tried to assess changes in these areas by relying on data from the interim and follow-up surveys, which asked village market and SACCO businesses, SACCO households, and health facilities about their operations in order to assess whether the Kigoma solar activity was successful in meeting these goals. Due, in part, to the small sample sizes available for these specific outcomes, no findings are statistically significant, but they provide descriptive information about the Kigoma solar activity's performance. For example, because it was believed that solar PV systems could help facilities stay open later into the evening, schools, health facilities, and businesses were asked about their daily hours of operation. Hours of operation increased between interim and follow-up for both groups, from 8.5 hours to 9.4 hours in the targeted group and 9.3 hours to 10.9 hours in the nontargeted group (Table IV.5, Appendix Table A.6). Due to the smaller increase in the targeted group compared with the nontargeted group, this produced a small, statistically insignificant net decrease in hours of operation of 0.7 hours. These same respondents were also asked about their total number of staff. Staff size grew in both groups over time, from 4.6 to 6.7 in the targeted group and from 5.0 to 5.5 in the nontargeted group, producing a statistically insignificant net change of 1.7 staff members.

Table IV.5. Investment, economic activities, and human capital accumulation

Outcome	Sample size	Adjusted target mean at follow-up	Adjusted target-nontarget difference at follow-up	Adjusted net change [a]
Schools, health facilities, market and SACCO businesses				
Hours of operation	76	9.4	-1.5	-0.7
Total staff	80	7	1	2
Business revenue-average (TZS) [b]	36	52,296	-68,037	299,132***
SACCO households				
Per capita household income (TZS)	21	766,384	239,785	284,306
Health facilities				
Availability of vaccine refrigerators	27	1.00	0.14	0.14

Source: Kigoma solar interim survey (2013) and follow-up survey (2015).

Notes: */**/***Estimate is statistically different from zero at the 0.10/0.05/0.01 level using a two-tailed test.

Results are based on regressions that control for respondent type, where appropriate. See Section II.C and Table A.6 for details.

[a] Adjusted net change refers to the differential in the differences between target and nontarget outcomes at the time of interim and follow-up data collection.

[b] Top coded at the 92nd percentile.

In addition, businesses were asked to report their average good-day, medium-day, and poor-day sales, which were averaged to compute a measure of average daily sales. Average daily sales were much bigger in the nontargeted group than in the targeted group at both time points: at interim, average daily sales were 31,803 TZS in the targeted group and 398,972 TZS in the nontargeted group. At follow-up, average daily sales were 52,296 in the targeted group and 120,334 TZS in the nontargeted group. These large differences highlight the difficulties in comparing targeted respondents with a group of respondents who were not selected in a rigorous way. The group of nontargeted businesses had much larger revenues to begin with, making them a poor comparison for the targeted group. Although these findings cannot be attributed to the Kigoma solar activity, we did observe a modest increase in average daily revenue in the targeted group from interim to follow-up and a large decrease in revenue for the nontargeted group, resulting in a positive and statistically significant net change. Since this change is due almost entirely to a drop in revenue for the nontargeted group we do not think it provides evidence that the program improved business revenue.

Availability of solar PV systems in households was also expected to increase per capita household income. Although per capita income was higher in the nontargeted group at the interim survey (412,236 TZS versus 367,715 TZS in the targeted group), it was higher in the targeted group at follow-up (766,384 TZS versus 526,599 TZS in the nontargeted group). This produced a large but not statistically significant net change of 284,306 TZS (Table IV.5).

In summary, these findings suggest that the Kigoma solar activity was not associated with any clear changes in the operations of businesses and community institutions, although, as with all of our results, the small sample sizes and the limitations of the purposively sampled nontarget group limit our ability to detect any such differences.

C. Results by respondent type

The Kigoma solar activity was also designed to influence outcomes specific to certain respondent types. Specifically, the availability of solar PV systems was expected to improve the availability of key medicines at health facilities. These results are presented in Table IV.6. Because the sample sizes by respondent type for these outcomes were very small, no statistical tests were conducted on the results in Table IV.6.

Table IV.6. Vaccine availability at health facilities

Follow-up outcomes	Targeted respondent sample size	Targeted respondent mean	Nontargeted respondent sample size	Nontargeted respondent mean	Difference
Health facilities					
Availability of polio vaccine	20	0.75	7	0.71	0.04
Availability of measles vaccine	20	0.90	7	0.43	0.47
Availability of BCG vaccine	20	0.90	7	0.71	0.19
Availability of rota vaccine	20	0.90	7	0.71	0.19
Availability of DPT vaccine	20	0.40	7	0.00	0.40
Availability of pentavalent vaccine	20	0.60	7	0.71	-0.11
Availability of tetanus vaccine	20	0.90	7	0.71	0.19
Availability of PCV vaccine	20	0.85	7	0.71	0.14
Availability of other vaccine	20	0.00	7	0.00	0.00
Availability of any vaccine	20	1.00	7	0.86	0.14

Source: Kigoma solar follow-up survey (2015).

Since no MCA-T solar-powered vaccine refrigerators had been installed in health facilities at the time of the interim survey, the interim findings related to solar refrigerators can be considered to be a true baseline for this particular domain. At the time of the interim survey, all targeted and nontargeted health facilities reported having a vaccine refrigerator available, although none of these refrigerators were solar powered. At follow-up, all targeted health facilities still had at least one vaccine refrigerator available, and all reported receiving a solar refrigerator from MCA-T. One nontargeted health facility no longer had a vaccine refrigerator at follow-up (Table IV.5).

With the exception of the nontargeted facility that did not have a vaccine refrigerator, all health facilities reported having at least some vaccines stocked in their refrigerators at follow-up (Table IV.6).[10] Polio, BCG, and measles vaccines were considered the most important vaccines for health facilities to have available. Most targeted facilities reported having each of these vaccines available at follow-up: out of 75 percent of targeted facilities had polio vaccines available on the day of the follow-up survey and 90 percent each had measles and BCG vaccines available. Availability of these vaccines appears to have been more limited in the nontargeted group: of seven nontargeted facilities, five had polio vaccines available, three had measles vaccines, and five had BCG vaccines. Vaccine availability was similar in both groups for other common vaccines, with the exception of DPT: eight targeted facilities and zero nontargeted facilities reported having these available on the day of the follow-up survey.Taken together, these respondent type-specific findings do not provide rigorous evidence of the impact of the Kigoma solar activity, but they do suggest that the activity may have helped to improve operations for some types of respondents.

[10] Health facilities were also asked about the availability of vaccines in the interim survey, but the targeted group and the nontargeted group were asked about vaccine availability at different time points: target group members were asked whether vaccines were available on the day of the interim survey, whereas nontarget group members were asked to recall the availability of vaccines six months prior to the interim survey. Because these data could not be compared, they were not used in this analysis.

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V. DISCUSSION AND CONCLUSION

The Kigoma solar activity provided an important pilot test of distributing and expanding the market for solar PV systems for households, businesses, and community institutions in rural communities in Tanzania. With solar energy becoming cheaper and easier to produce, it is important to generate evidence on how such activities can support the growing energy needs of rural communities (Joby 2016; Mooney 2016). Although the evaluation of the Kigoma solar activity was not designed to provide rigorous estimates of impacts, it offers important insights into how to distribute and ensure usage of solar systems, and how the adoption of these systems may be associated with energy use, income, and well-being of people in the affected communities. In this section, we provide a summary of key findings related to the implementation and performance of the Kigoma solar activity and conclude with a discussion of the implications of these findings for future programs and policies.

A. Summary of findings: implementation domains

Implementation of the Kigoma solar activity generally occurred according to plan. The Kigoma solar activity was a complex activity that involved the distribution of different types of solar PV systems to a number of different types of individuals and institutions. In spite of these complexities, we found that implementation was generally successful, with most targeted institutions receiving MCA-T-funded solar PV systems as expected. Schools, health facilities, and businesses in village markets generally received access to solar PV systems according to plan, and individual households and businesses purchased systems through SACCOs.

Specific implementation challenges limited our ability to evaluate certain components of the activity. For example, during the marketing phase, SMS messages were intended to provide an important way to disseminate information about the activity to large audiences, but in the follow-up survey, we found that no respondents had received these messages. This may be the result of a translation issue in the survey, but it may also be that these messages were not appropriately targeted, or there may have been other reasons why they were unpopular among respondents. There also appears to have been very limited uptake of solar PV systems among fishers, because no fishers in our study sample reported having participated in the activity, though the interim report did find some use among fishers (Busalama 2013). Because of this, we were unable to assess how the activity affected fishers' operations in these communities and we omit fishers from most of our analyses unless noted otherwise. Finally, we found that some survey respondents in the nontargeted group reported receiving MCA-T-funded solar PV systems. This may reflect an error in the implementation process, or it may reflect some confusion in a geographic area that may have had multiple funders or implementers working on solar energy projects simultaneously. The follow-up survey was not designed to fully assess these types of implementation issues, but our findings point to a need for robust quantitative and qualitative data collection in order to fully understand implementation challenges for such activities.

As use of solar PV systems grows, so do expectations for their performance and capacity. Our implementation findings indicate that solar PV systems are being used and are helping to meet the energy needs of most respondents in the targeted communities. The use of solar PV systems increased slightly over time among both targeted and nontargeted respondents, which suggests that the systems are growing in popularity. However, the percentage of MCA-T system users who reported that their solar PV systems met their energy needs fell over time, from 42 percent in the interim survey to 31 percent in the follow-up. This suggests that as solar PV systems become more common and as electricity becomes cheaper and more efficient, community members' needs and expectations regarding the availability of electricity may be growing and/or that the systems may be degrading over time.[11]

Solar PV systems face quality issues, and a lack of maintenance and repair training, as well as high costs for installation and repairs, may limit their utility and popularity. As the demand for solar PV systems grows, it will be important for providers to ensure that the systems available to users are of high quality and remain functional. Our implementation findings suggest that although MCA-T-funded systems may have performed better than other systems, all systems experienced problems fairly frequently, and only a small proportion of targeted respondents received the maintenance and repair training that was designed to be a component of the Kigoma solar activity. The high rate of solar PV usage among targeted respondents suggests that these issues were not major deterrents to use; however, over time, as systems break or experience more problems, if users or other members of the community do not have the training required to maintain these systems, their use may decline. In addition, installation costs were observed to be quite high, and some respondents reported high costs for repairs as well. These costs may be a barrier to use, and subsidies may be needed in order to increase uptake of solar PV systems.

B. Summary of findings: performance domains

The use of solar PV systems increased over time, among both targeted and nontargeted respondents, and was consistently high in the targeted group at interim and follow-up. Solar PV use was also higher in the targeted group based on the retrospective baseline data, and grew more in the targeted group than in the nontargeted group between baseline and interim, suggesting that most changes in solar PV use likely occurred in the period shortly after targeted respondents received their systems. Between the time of the interim and follow-up surveys the nontargeted group actually started to catch up to the targeted group in terms of solar PV use. The large amount of solar PV use in the nontargeted group may reflect the fact that other donors and implementers were working on solar programs in the Kigoma region at the same time, and may also point to the fact that these systems are growing in popularity in the study area.

We also found that the Kigoma solar activity may be associated with changes in the use of certain types of non-electric energy sources among respondents. Specifically, we found that **liquid fuel use was lower among targeted respondents than nontargeted respondents both at interim and at follow-up**, which was consistent with our hypothesis that solar PV systems

[11] Satisfaction with solar PV systems may have decreased over time if perceptions of the alternatives improved—for example, newer solar PV systems that produce more power may have become available, and/or the availability of other sources of electricity, such as the grid, may have increased over time for some respondents. This relates to what is commonly referred to as the "Jevons effect" in energy economics (Jevons 1866) in the sense that the newer solar PV systems and/or increased availability of other sources can be thought of as the "technological" changes that increased the amount of electricity customers could get for a given price, and thereby reduced satisfaction with the current solar PV systems that had relatively limited capacity.

could help to meet many of the same energy needs that liquid fuel sources typically meet, such as providing light and powering appliances.

Findings from the performance domains provide limited evidence of association between the Kigoma solar activity and improvements in outcomes related to investments, economic activities, and human capital accumulation for specific respondent types. Note that our small sample sizes limit our ability to assess these outcomes deeply. After controlling for respondent type, we found no statistically significant differences between targeted and nontargeted respondents in the number of staff or hours of operation of schools, health facilities, or businesses; per capita household income; or the availability of vaccine refrigerators at health facilities. We found a large and statistically significant net increase in average daily business revenue, but this finding is likely a result of a lack of balance between the targeted and nontargeted businesses in our sample; nontargeted businesses reported much larger revenue on average than targeted businesses at interim. We found that although most targeted and nontargeted health facilities had vaccine refrigerators available, key vaccines were more commonly found in targeted health facilities than in nontargeted facilities.

C. Limitations

The nonrigorous methods used in this evaluation also limit the results of our findings. The sampling methods used to select survey participants, especially the decision to select nontargeted respondents purposively, resulted in a lack of baseline equivalence between the two groups that may have produced some biased results, such as in the findings for business revenues. In addition, although we did not use much of the retrospective baseline data, the retrospective data that we did use may be subject to recall bias, because users of solar PV systems may recall their energy use differently than non-users. Further, because the interim survey was conducted after most of the activity's components had been rolled out, we did not have true baseline measures and thus could not fully assess the impact of the activity. We were still able to make use of much of the data collected in the interim survey, but data quality issues further limited our use of this information. The pen-and-paper surveys produced a number of data entry issues that we were unable to interpret or correct. In contrast, the capabilities of the computer-based survey platform used for the follow-up survey ensured that appropriate skip patterns were followed and that any unusually low or high values were reviewed and discussed with the respondent.

D. Conclusion

The growing focus on improving access to electricity in sub-Saharan Africa, and in Tanzania in particular, has provided the political will necessary to test and develop programs to deliver electricity to rural and other hard-to-reach populations. Given the high costs associated with expanding access to grid electricity and the falling cost of solar energy worldwide, programs such as the Kigoma solar activity may offer a relatively low-cost and effective way to bring electric energy to many rural Tanzanians. Such efforts could help change how people and institutions use energy sources, reduce energy costs for individual households and businesses, enable schools and health facilities to serve people better, and ultimately reduce poverty.

It is in this context that the Kigoma solar activity was implemented, and our findings suggest that the activity may have achieved some of these expected outcomes. Specifically, the overall high use of and satisfaction with solar PV systems, coupled with some changes in the consumption of liquid fuels, suggest that the activity may have helped to encourage solar energy use. Although there is some evidence to support the hypothesis that increased solar energy consumption could help lead to longer-term outcomes, such as improved facility operations and increased income and revenues, our results in this area were generally very imprecise.

Our study provides rich, high quality data on solar energy use, and although our evaluation was not a rigorous assessment of the Kigoma solar activity's impacts, it provides a basis for evaluations of future efforts to expand access to solar energy. Given the promise of programs like the Kigoma solar activity and the limitations of our evaluation, funders and implementers of similar activities should consider implementing them in ways that allow for longer-term and more rigorous evaluations. In particular, studies with true baseline data, comparison groups selected to better match the intervention groups, and larger sample sizes would allow for more rigorous estimations of impacts. Comparison groups are particularly important given our evidence that solar power was increasing for all respondents, including those not targeted for this program. Designing implementation of an activity to allow for a randomized or quasi-experimental evaluation design would also enhance the quality of evidence available for the effect of such activities. Longer-term evaluations may also help to detect long-term outcomes, such as changes in facility operations or household per capita income; we did not observe any differences in these outcomes, perhaps because they may take longer to achieve. Finally, such evaluations could benefit from including a qualitative component to help build an in-depth understanding of certain elements of program implementation, especially any questions around knowledge of solar energy, why solar PV systems were used or not used, and the perceived quality and reliability of these systems. Future evaluations of efforts to expand access to solar energy that address some of these issues could help to produce more rigorous evidence on how such efforts work and to what extent they can be used to meet the energy needs of sub-Saharan African populations.

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APPENDIX A

SUPPLEMENTARY TABLES

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In this appendix, we present additional statistics for the respondent outcomes from Chapter IV. These are all based on equation 2 which is repeated below.

(2) $$Y_{it} = \beta_0 + \beta_1 \text{Targeted}_i + \beta_2 \text{Post}_t + \beta_3 (\text{Targeted}_i * \text{Post}_t) + \alpha_i + \varepsilon_{it}$$

For each outcome domain, we report the following: the adjusted net-change (β_3), the adjusted target-nontarget difference at baseline (β_1), the adjusted target-nontarget difference at follow-up ($\beta_1 + \beta_3$), the adjusted mean in the targeted group at interim (that is, the unadjusted mean in the nontargeted group at interim + β_1), the adjusted mean in the targeted group at follow-up (that is, unadjusted mean in the nontargeted group at interim + β_1 + β_2 + β_3), the adjusted mean in the nontargeted group at follow-up ($\beta_0 + \beta_2$), and the unadjusted mean in the nontargeted group at interim. For each adjusted difference and net-change, we report two-tailed test p-values (except for outcomes with fewer than 30 observations). For outcomes that were presented as top coded in the main report, we also show the results for the non-top-coded version. All of these results are based on regressions that control for respondent type. See Section II.C for details.

Table A.1. Energy source and average monthly use, retrospective baseline and follow-up

						Adjusted target-nontarget difference at baseline		Adjusted target-nontarget difference at follow-up		Adjusted net change [a]	
Outcome	Sample size	Adjusted target mean at follow-up	Adjusted target mean at baseline	Adjusted nontarget mean at follow-up	Nontarget mean at baseline	Value	*p*-value	Value	*p*-value	Value	*p*-value
Currently using energy source (fraction)											
Kerosene	102	0.22	0.81	0.29	0.81	0.01	0.92	-0.07	0.46	-0.08	0.53
LPG	102	0.03	0.15	0.16	0.23	-0.07	0.14	-0.14	0.01	-0.06	0.33
Liquid fuels	102	0.26	0.82	0.42	0.81	0.01	0.86	-0.16	0.06	-0.18	0.14
Solar PV systems	102	0.88	0.25	0.61	0.13	0.12	0.11	0.27	0.00	0.15	0.22
Average monthly energy use (in liters, unless otherwise noted)											
Kerosene	101	-0.82	6.38	1.75	41.20	-34.82	0.08	-2.58	0.29	32.24	0.13
Kerosene [b]	101	0.47	6.09	1.59	8.67	-2.57	0.35	-1.13	0.14	1.45	0.62
LPG	102	0.31	5.63	5.25	6.07	-0.44	0.78	-4.95	0.01	-4.51	0.07
Liquid fuels	102	-0.80	11.73	6.77	45.94	-34.21	0.08	-7.57	0.01	26.64	0.20
Liquid fuels [c]	102	0.71	11.34	6.77	14.40	-3.06	0.30	-6.06	0.00	-3.00	0.42
Solar PV systems (hours)	102	399.51	98.24	174.19	55.31	42.94	0.29	225.32	0.00	182.38	0.00

Source: Kigoma solar interim survey (2013) and follow-up survey (2015)

Notes: Results are based on regressions that control for respondent type. See Chapter 2 section C and beginning of this appendix for details.

[a] Adjusted net change refers to the differential in the differences between target and nontarget outcomes at the time of interim and follow-up data collection, controlling for respondent type.

[b] Top coded at the 93rd percentile; eight observations top coded

[c] "Liquid fuels" is the sum of kerosene and LPG, and includes kerosene top coded as described above

Table A.2. Electricity source and average monthly use

Outcome	Sample size	Adjusted target mean at follow-up	Adjusted target mean at interim	Adjusted nontarget mean at follow-up	Nontarget mean at interim	Adjusted target-nontarget difference at interim		Adjusted target-nontarget difference at follow-up		Adjusted net change [a]	
						Value	*p*-value	Value	*p*-value	Value	*p*-value
Currently using electricity source (fraction)											
Electric grid	102	0.02	0.00	0.06	0.00	0.00	0.66	-0.05	0.29	-0.05	0.29
Dry cell battery	102	0.36	0.73	0.48	0.81	-0.08	0.37	-0.12	0.24	-0.04	0.73
Car/motorcycle battery	102	0.06	0.08	0.03	0.10	-0.02	0.73	0.03	0.48	0.05	0.50
Generator	102	0.11	0.11	0.10	0.16	-0.05	0.49	0.01	0.86	0.06	0.38
Solar PV systems	102	0.89	0.94	0.613	0.29	0.65	0.00	0.274	0.00	-0.38	0.00
Average monthly electricity use (in hours)											
Grid electricity	102	2.39	0.27	9.68	0.00	0.27	0.66	-7.29	0.29	-7.56	0.29
Dry cell battery	102	45.43	121.59	49.35	160.94	-39.35	0.22	-3.93	0.79	35.42	0.28
Car/motorcycle battery	102	13.65	31.82	11.61	34.84	-3.02	0.91	2.03	0.87	5.06	0.87
Electricity from generators	102	13.29	15.19	13.55	19.84	-4.65	0.65	-0.26	0.98	4.39	0.75
Solar electricity	102	397.05	344.45	174.19	108.53	235.92	0.00	222.86	0.00	-13.06	0.81

Source: Kigoma solar interim survey (2013) and follow-up survey (2015)

Notes: The average monthly hours of electricity use includes the zero hours for non-users. Results are based on regressions that control for respondent type. See Chapter 2 section C and beginning of this appendix for details.

[a] Adjusted net change refers to the differential in the differences between target and nontarget outcomes at the time of interim and follow-up data collection, controlling for respondent type.

Table A.3. Electricity expenditures (TZS)

Outcome	Sample size	Adjusted target mean at follow-up	Adjusted target mean at interim	Adjusted nontarget mean at follow-up	Nontarget mean at interim	Adjusted target-nontarget difference at interim		Adjusted target-nontarget difference at follow-up		Adjusted net change a	
						Value	*p*-value	Value	*p*-value	Value	*p*-value
Monthly expenditure											
Grid electricity	102	535	112	4,516	0	112	0.62	-3,981	0.20	-4,094	0.20
Dry cell batteries	96	987	2,063	1,326	2,261	-197	0.67	-340	0.45	-142	0.83
Total cost to purchase devices											
Generators	96	103,280	20,131	68,208	5,556	14,576	0.28	35,072	0.70	20,496	0.82
Generators [b]	96	18,505	19,252	15,870	5,556	13,696	0.18	2,635	0.82	-11,061	0.45
Solar PV systems	56	168,960	241,851	108,634	210,000	31,851	0.81	60,327	0.05	28,476	0.84
Solar PV systems [c]	56	179,049	227,020	109,854	79,286	147,735	0.01	69,195	0.02	-78,540	0.22

Source: Kigoma solar interim survey (2013) and follow-up survey (2015)

Notes: Results are based on regressions that control for respondent type. See Chapter 2 section C and beginning of this appendix for details.

[a] Adjusted net change refers to the differential in the differences between target and nontarget outcomes at the time of interim and follow-up data collection, controlling for respondent type.

[b] Follow-up observations top coded at the 97th percentile; three observations top coded

[c] Interim observations top coded at the 96th percentile; three observations top coded

Table A.4. Monthly non-electric energy consumption

Outcome	Sample size	Adjusted target mean at follow-up	Adjusted target mean at interim	Adjusted nontarget mean at follow-up	Nontarget mean at interim	Adjusted target-nontarget difference at interim		Adjusted target-nontarget difference at follow-up		Adjusted net change [a]	
						Value	*p*-value	Value	*p*-value	Value	*p*-value
Currently using non-electric source (fraction)											
Kerosene	102	0.22	0.36	0.29	0.58	-0.22	0.03	-0.07	0.46	0.15	0.25
LPG	102	0.03	0.14	0.16	0.23	-0.09	0.08	-0.13	0.01	-0.05	0.47
Liquid fuels	102	0.25	0.43	0.42	0.58	-0.15	0.12	-0.17	0.05	-0.02	0.85
Small candle	102	0.00	0.03	0.00	0.06	-0.04	0.46	0.00	0.76	0.04	0.46
Medium candle	102	0.03	0.05	0.13	0.13	-0.08	0.21	-0.09	0.12	-0.01	0.87
Large candle	102	0.00	0.02	0.00	0.03	-0.02	0.64	0.00	0.55	0.02	0.61
Firewood	102	0.48	0.44	0.55	0.48	-0.05	0.65	-0.07	0.50	-0.02	0.86
Animal dung	102	0.00	0.00	0.00	0.00	0.00		0.00		0.00	
Straw	102	0.00	0.02	0.00	0.03	-0.02	0.64	0.00	0.55	0.02	0.61
Tree leaves	102	0.01	0.03	0.00	0.13	-0.09	0.13	0.01	0.42	0.10	0.12
Charcoal	102	0.36	0.50	0.45	0.35	0.15	0.18	-0.09	0.42	-0.24	0.06
Solid fuels	**102**	**0.68**	**0.68**	**0.81**	**0.68**	**0.00**	**0.98**	**-0.13**	**0.13**	**-0.13**	**0.25**
Average monthly non-electric consumption											
Kerosene (liter)	102	0.74	1.60	1.52	3.27	-1.67	0.10	-0.78	0.23	0.89	0.34
LPG (liter)	102	0.33	5.33	5.25	6.01	-0.68	0.65	-4.92	0.01	-4.25	0.09
Liquid fuels (liter)	**102**	**1.07**	**6.93**	**6.77**	**9.27**	**-2.35**	**0.24**	**-5.70**	**0.00**	**-3.35**	**0.22**
Small candle (counts)	102	0.11	3.95	0.00	0.21	3.74	0.35	0.11	0.85	-3.63	0.35
Medium candle (counts)	102	0.50	0.20	3.52	0.47	-0.27	0.48	-3.02	0.15	-2.75	0.22
Large candle (counts)	102	0.09	0.94	0.00	0.23	0.71	0.46	0.09	0.54	-0.62	0.49
Firewood (kg)	102	78.86	121.00	181.45	61.31	59.70	0.36	-102.59	0.13	-162.29	0.03
Firewood (kg)[b]	102	69.33	36.83	100.81	38.73	-1.90	0.92	-31.47	0.20	-29.58	0.32
Animal dung (kg)	102	0.00	0.00	0.00	0.00	0.00		0.00		0.00	
Straw (kg)	102	0.00	0.00	0.00	0.00	0.00		0.00		0.00	
Tree leaves (kg)	102	0.01	0.01	0.00	0.16	-0.16	0.32	0.01	0.63	0.16	0.32
Charcoal (kg)	102	-13.04	468.05	25.27	36.10	431.95	0.31	-38.32	0.57	-470.27	0.31

TABLE A.4 (*continued*)

Outcome	Sample size	Adjusted target mean at follow-up	Adjusted target mean at interim	Adjusted nontarget mean at follow-up	Nontarget mean at interim	Adjusted target-nontarget difference at interim		Adjusted target-nontarget difference at follow-up		Adjusted net change [a]	
						Value	*p*-value	Value	*p*-value	Value	*p*-value
Charcoal (kg)[c]	102	18.73	43.06	25.27	36.10	6.96	0.70	-6.54	0.40	-13.51	0.44
Solid fuels(kg)	**102**	**65.89**	**589.37**	**207.08**	**97.65**	**491.72**	**0.25**	**-141.19**	**0.17**	**-632.91**	**0.18**
Solid fuels(kg)[d]	**102**	**88.14**	**80.21**	**126.43**	**75.07**	**5.14**	**0.85**	**-38.30**	**0.14**	**-43.44**	**0.24**

Source: Kigoma solar interim survey (2013) and follow-up survey (2015)

Notes: Results are based on regressions that control for respondent type. See Chapter 2 section C and beginning of this appendix for details.

Blank p-values indicate no variation in the outcome.

[a] Adjusted net change refers to the differential in the differences between target and nontarget outcomes at the time of interim and follow-up data collection, controlling for respondent type.

[b] Interim and follow-up observations top coded at the 96th percentile; four observations top coded

[c] Interim observations top coded at the 97th percentile; three observations top coded

[d] “Solid fuels” is the sum of all fuels from small candles through charcoal, and includes firewood and charcoal top coded as described above

Table A.5. Average monthly non-electric energy expenditures (TZS)

Outcome	Sample size	Adjusted target meat at follow-up	Adjusted target mean at interim	Adjusted nontarget mean at follow-up	Nontarget mean at interim	Adjusted target-nontarget difference at interim		Adjusted target-nontarget difference at follow-up		Adjusted net change [a]	
						Value	*p*-value	Value	*p*-value	Value	*p*-value
Kerosene (liter)	95	1,329	3,804	4,176	7,465	-3,661	0	-2,847	815	1	0
LPG (liter)	83	0	0	0	0	0	-	0	0	-	-
Small candle (counts)	102	11	398	0	38	360	0	11	-349	0	1
Medium candle (counts)	101	149	49	1,045	139	-89	0	-896	-807	0	0
Large candle (counts)	101	50	472	6	0	472	0	44	-428	0	1
Firewood (kg)	80	4,684	298	19,895	652	-354	1	-15,210	-14,856	0	0
Firewood (kg)[b]	102	0	0	0	0	0		0	0	0	
Animal dung (kg)	100	0	0	0	0	0		0	0	0	
Straw (kg)	97	1	2	0	36	-34	0	1	35	0	1
Tree leaves (kg)	96	4,109	13,252	8,480	2,383	10,868	0	-4,371	-15,239	0	0
Charcoal (kg)	96	4,694	3,804	8,391	2,383	1,420	0	-3,698	-5,118	0	0
Charcoal (kg)[c]	74	8,494	16,891	43,674	3,953	12,938	0	-35,180	-48,118	0	0
Solid fuels(kg)	74	9,230	4,825	28,910	3,953	871	1	-19,680	-20,551	0	0
Solid fuels(kg) [d]	57	12,332	7,792	49,380	5,817	1,975	1	-37,048	-39,023	0	0
All non-electric energy sources)	57	11,709	7,465	33,981	5,817	1,648	1	-22,272	-23,921	0	0
All non-electric energy sources) [e]	95	1,329	3,804	4,176	7,465	-3,661	0	-2,847	815	1	0

Source: Kigoma solar interim survey (2013) and follow-up survey (2015)

Notes: Results are based on regressions that control for respondent type. See Chapter 2 section C and beginning of this appendix for details.

Blank p-values indicate no variation in the outcome.

[a] Adjusted net change refers to the differential in the differences between target and nontarget outcomes at the time of interim and follow-up data collection, controlling for respondent type.

[b] Interim and follow-up consumption observations top coded at the 96th percentile; four observations top coded

[c] Interim consumption observations top coded at the 97th percentile; three observations top coded

[d] "Solid fuels" is the sum of all fuels from small candles through charcoal, and includes With firewood and charcoal consumption top coded as described above

[e] "All non-electric energy sources" includes all energy sources in this table, and includes firewood and charcoal consumption top coded as described above

Table A.6. Investment, economic activities, and human capital accumulation

Outcome	Sample size	Adjusted target mean at follow-up	Adjusted target mean at interim	Adjusted nontarget mean at follow-up	Nontarget mean at interim	Adjusted target-nontarget difference at interim		Adjusted target-nontarget difference at follow-up		Adjusted net change[a]	
						Value	*p*-value	Value	*p*-value	Value	*p*-value
School, health facilities, market and SACCO businesses											
Hours of operation	76	9.4	8.5	10.9	9.3	-0.8	0.29	-1.5	0.20	-0.7	0.56
Total staff	80	7	5	5	5	0	0.68	1	0.14	2	0.11
Business revenue-average (TZS)	36	63,826	43,233	170,574	827,167	-783,933	0.06	-106,748	0.23	677,186	0.13
Business revenue-average (TZS)[b]	36	52,296	31,803	120,334	398,972	-367,169	0.00	-68,037	0.11	299,132	0.00
SACCO households											
Per capita household income (TZS)	21	766,384	367,715	526,599	412,236	-44,521	-	239,785	-	284,306	-
Health facilities											
Availability of vaccine refrigerators (fraction)	27	1.00	1.00	0.86	1.00	0.00	-	0.14	-	0.14	-

Source: Kigoma solar interim survey (2013) and follow-up survey (2015)

Notes: Results are based on regressions that control for respondent type. See Chapter 2 section C and beginning of this appendix for details.

P-values set to “-“ are missing because of small sample sizes.

[a] Adjusted net change refers to the differential in the differences between target and nontarget outcomes at the time of interim and follow-up data collection, controlling for respondent type.

[b] Top coded at the 92nd percentile.

APPENDIX B

STAKEHOLDER COMMENTS AND EVALUATOR RESPONSES

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Table B.1. Stakeholder comments and evaluator responses

Page Number	Comment	MPR responses
xii, and throughout	The word "beneficiary" is used throughout the report in a way that is inconsistent with MCC's definition of a beneficiary: individuals who realize improved standards of living as a result of economic gains generated by the project, either through higher real incomes or through expenditure savings. Suggest clearly defining how the term is used in the report or find a different term.	We have replaced the word "beneficiary" with "respondent" throughout the report (since we had used "beneficiary" to describe the different types of respondents in our sample.)
xiii	"Community members' needs and expectations… may be degrading over time." Could this also be a situation similar to a Jevons effect - with energy now cheaper and more efficient, households find more uses for it, boosting their demand?	We agree, and have added it as a possible explanation for the decline in the percentage of MCA-T system users who said the system met their needs. See added explanation in footnote 10.
2	"4.75 million." Please double-check this number. My records indicate it was around $7.9 million for the works, supervision, feasibility study and technical assistance.	We have revised this number to $11 million based on what was reported in MCC's draft Summary of Findings for the Kigoma solar evaluation.
11	"No fishers reported." This is the first issue related to the sampling.	Addressed below.
17	"Lists of participating businesses… may not have been completely accurate." This is the second problem related to the sampling.	Addressed below.
17, footnote	SMS messages are easy to ignore or delete, so a low response rate is not entirely unexpected. What is a typical response rate for such a campaign?	Results from studies of SMS campaigns across a range of topics and geographies suggests that "response" to these campaigns (which could take the form of responding to the SMS, visiting a website, or taking some other action) tends to be quite low -- around 12 percent on average. If this SMS campaign had a similarly low response rate, this would help explain why none of the sampled survey respondents replied to SMS messages and why none recalled seeing or participating in the campaign.
30	"These large differences highlight the difficulties in comparing targeted respondents with a group of respondents who were not selected in a rigorous way." This is a third problem related to the sampling.	Addressed below.
35	"The nonrigorous methods used in this evaluation also limit the results of our findings." Given the problems with sampling identified throughout the report and the non-rigorous methods, what is your level of confidence in the quality of the data and the results?	As we have noted, our findings should not be interpreted as estimates of impacts of the evaluation. In spite of the limitations of our study, the availability of high-quality follow-up data and our ability to use much of the interim data allowed us to generate findings that point to future directions for research and evaluation of similar programs. We have added a separate "Limitations" section to make these issues clear.

TABLE B1 *(continued)*

Page Number	Comment	MPR responses
xi, figure ES.1	This program logic diagram differs from the standard MCC format. They should probably align.	We have revised our logic diagram to follow the same language and set of steps as the standard MCC format.
xii, figure ES.1	I don't understand the explanation of the PV system and purpose for Village Markets. Unlike BMUs and individuals, I thought there was a PV system installed in the markets that allowed businesses to individually connect for lighting? The explanation of the intervention isn't clear.	Table III.1 on page 15 explains this in more detail. We have revised the description in Table ES1 to align with this.
Throughout	I had understood the acronym BMU stood for Beach Management Unit. As long as somewhere in the fieldwork it was made clear that the B stands for Boat, that's fine.	We have revised this to "Beach Management Unit" throughout the report.
11	First paragraph about fishers. I agree this finding indicates there may have been an error in sampling the respondents, but was there any follow-up to investigate whether this could have been an issue with project implementation?	Yes- we contacted the project director at CAMCO for this study and MCC to see if either organization had an explanation for this finding. The CAMCO project director did not respond and MCC said that their staff did not have an explanation. We also reviewed our data but unfortunately the survey instrument did not contain questions that would have allowed us to assess why fishers may not have received MCA-T systems.
13	I believe this page has the first reference to dispensaries. I suggest specifying health dispensaries.	We have made this change, specifying "health dispensaries" on page 1, where we first mention dispensaries.
17	I think a bit more discussion of the non-targeted beneficiaries who received MCA-T systems would be helpful here to make sure the reader understand that this was an unintended/odd outcome. Later in the doc (maybe conclusion) you talk a bit more about why this may have occurred, and I suggest you include one or two more sentences just highlighting the fact that this was an implementation finding and why it might have occurred.	We have added some text at the end of this paragraph (at the top of page 18) to highlight that this was an unexpected finding.
13	The explanation of adjusted vs. unadjusted means might be confusing. Think about adding a sentence or two to make it more intuitive to readers.	We have added some additional explanation here and throughout the report to clarify the meaning of unadjusted and adjusted means.
24	Potential typo: The retrospective data suggest relatively little difference in hours of use of PV systems before the activity as implemented—49 hours per month for the nontargeted group and 86 for the targeted group, resulting in a net change of 154 hours that was statistically significant at the 1 percent level (Table A.1). I think it should say "before the activity was implemented"	Revised.

TABLE B1 *(continued)*

Page Number	Comment	MPR responses
31	Potential typo: Taken together, these beneficiary-specific findings do not provide rigorous evidence of the impact of the Kigoma solar activity, but they do suggest that the activity may have helped to improve operations for some types of beneficiary. "some types of beneficiaries"	Revised.
5	BMU is Beach Management Unit	We have revised this to "Beach Management Unit" throughout the report.
9	Last paragraph. The BMU program was a demonstration program. None of the program descriptions indicate that the systems would be sold to the boat owners or associations. It is not clear where the plan for initial purchases was developed or implemented. The demonstration program was intended to spur vendors to pursue more sales after the proof of operation. Perhaps potential buyers were noted as purchasers instead of the actual recipients of the systems.	Thank you for this additional information about the BMU program. The description of the sampling of fishers for the 2013 performance evaluation does state that fishers were selected from lists of those who purchased solar PV systems from BMUs. However, it does seem possible that the lists used for sampling were in fact lists of potential buyers, not lists of actual recipients. We have added a footnote explaining this on page 11, where we note the sampling issues with fishers.
General	Awareness is needed for non-grid people to use solar power. Costs of installation are too high. (Subsidies are needed)	We agree that more awareness may be needed to promote solar power use among people who are not connected to the grid. We note in Chapter V that better targeting of some advertising messages could have helped to promote the solar PV systems more. We have revised the text to further emphasize the importance of building awareness of solar power. We have also revised the text to note that the high cost of solar system installations may be a barrier to use and that subsidies may be needed in order to increase uptake of such systems.
17	"All targeted health facilities also received a solar-powered vaccine refrigerator (data not shown)." Why are data not shown?	Table III.3 has been revised to show vaccine refrigerator installations at health centers and dispensaries.

Note: The page numbers in this table refer to the draft of the report that was reviewed by the stakeholders.

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