# MEASURING THE HAPPINESS, MATERIAL WELL-BEING AND LIGHTING IMPACTS OF SOLAR HOME SYSTEMS IN TANZANIA: A RANDOMIZED CONTROL DESIGN

By

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April 24, 2015

Masters project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment of Duke University

Executive Summary

# MEASURING THE HAPPINESS, MATERIAL WELL-BEING AND LIGHTING IMPACTS OF SOLAR HOME SYSTEMS IN TANZANIA: A RANDOMIZED CONTROL DESIGN

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Throughout the world, nearly 1.3 billion people lack access to modern forms of energy such as electricity. In order to fill this gap, a number of companies have entered the solar residential market in Africa to provide rural and poor households with a means of accessing lighting and mobile-charging services. Off-Grid Electric (OGE), a Tanzania-based company which uses a third-party ownership model, is rapidly spreading in rural and peri-urban areas throughout the country. Despite the success of OGE and similar organizations, few if any rigorous studies have been done to evaluate the effects of energy access on outcomes such as health, education, income and welfare, which many solar companies, NGOs and multi-lateral institutions identify as the impact of their work. Using OGE as a case study, this project presents a full plan for a randomized control trial (RCT) to measure the impact of solar-home systems (SHS) on happiness, material well-being and lighting consumption on rural households in Tanzania.

The first part of this paper reviews the provision and use of energy in Tanzania, including the role of the national utility in electrification, the market for off-grid energy products, and OGE's growth as a distributed energy provider.

The second part of this paper presents a meta-analysis of existing studies on the impacts of electrification and off-grid energy deployment. Using a database of econometric studies and evaluations, I conclude that work in the field of energy access evaluations remains in the early stages.

In the third part of the paper, I present a plan for a randomized-control trial (RCT) which measures the impact of OGE's product on happiness, material well-being and lighting. The RCT plan includes a sampling strategy, proposed indicators, proposed data collection instruments, a data collection protocol and an estimation strategy.

Using the template provided in this report, OGE will be able to carry out a rigorous study which measures the impact of its solar product on important human development outcomes. Such research will not only add to the body of knowledge concerning energy access but can also be leveraged by the company to attract new investment and market its product more effectively.

Approved

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Abstract:

*Throughout the world, nearly 1.3 billion people lack access to electricity. In order to fill this gap, a number of companies have entered the solar residential market in Africa to provide rural and poor households with a means of accessing lighting and mobile-charging services. Off-Grid Electric (OGE), a Tanzania-based company which uses a third-party ownership model, is rapidly spreading in rural areas throughout the country. Despite the success of OGE and similar organizations, few if any rigorous studies have been done to evaluate the effects of energy access on outcomes such as health, education, income and welfare, which many solar companies, NGOs and multi-lateral institutions identify as the impact of their work. Using OGE as a case study, this project presents a full plan for a randomized control trial (RCT) to measure the impact of solar-home systems (SHS) on happiness, material well-being and lighting consumption on rural households in Tanzania.*

## ***Introduction***

*Purpose*

Currently, 620 million individuals in Sub-Saharan Africa lack access to electricity (IEA, 2014). Increasingly cognizant of the role that energy access plays in poverty alleviation, international organizations such as The World Bank and the United Nations have pledged to help these individuals secure access to modern sources of energy by 2030. The Sustainable Access for All (SE4ALL) program, for instance, hopes to accomplish this goal by deploying renewable energy (RE) and energy efficiency (EE) programs (Ban Ki-moon, 2011).

A wide variety of technologies and approaches have been adopted in order to increase access to energy. Traditional electrification programs, which seek to expand the national grid to previously unelectrified areas, are being supplemented with off-grid approaches. These include micro-grids, solar-home systems (SHS), solar lighting products (lanterns, lamps), wind turbines, micro and pico-hydro units, biogas units, geothermal plants, diesel generators, and a plethora of other innovations. While the benefits of access to electricity and lighting are assumed to be substantial and are disputed by few, very little is known about the relationship between access to energy and indicators of well-being such as health, income, education and happiness (Torero, 2014).

The goal of this report is to analyze existing studies on the impact of energy access and present a proposal for an impact evaluation of a company in Tanzania. In the first part of the study, I will present the results of a meta-analysis which examines publicly available impact evaluations, monitoring studies and econometric papers about the relationship between energy access and key human development indicators. The second part of the report is a comprehensive evaluation proposal for a Tanzanian SHS

company which can be used to evaluate the impacts of energy access on happiness, material well-being and lighting.

*Background*

Tanzania is an East-African country of 49.2 million people where roughly 14.8% of the population has access to electricity (The World Bank, 2014). According to the Tanzanian government, 14% of the country is electrified with an urban-rural split of 12% and 2%, respectively (Msyani, 2013).[1] In much of the country, biomass and kerosene continue to be used for cooking, lighting and other needs. In 2007, the last year for which national energy-use data is available, kerosene was the primary source of fuel for lighting (83% of households surveyed) while cooking was largely done with firewood (73.3% of households). This same analysis suggests that households primarily use electricity for lighting (12% of households) as opposed to cooking (0.5% of households) and that contrary to the energy ladder hypothesis,[2] even electrified Tanzanian households use a mix of fuels for different purposes (Malti and Mnenwa, 2011).

In order to increase the percentage of the population with access to electricity, the Tanzanian government, in its 2012 Power System Master Plan, set a 75% electrification target by the year 2035 (Ministry of Energy and Minerals, 2012). The effort is being led by the government's Rural Energy Agency (REA) and the state-owned utility, the Tanzania Electric Supply Company Ltd (TANESCO). As a regulated entity with vertically integrated generation, transmission and distribution functions, TANESCO will undergo restructuring (unbundling) to increase efficacy and service quality (Ministry of Energy and Minerals, 2014). From 2012-2013, the last year for which financial data was publicly available, TANESCO increased the volume of customers receiving electricity services by 60.8% from 88,996 to 143,113 customers (National Audit Office, 2013). Demand for energy services is growly rapidly and far outstrips forecasted supply within the next few years (Ministry of Energy and Minerals, 2013).

Even as TANESCO continues to add customers and expand its service territory, off-grid electricity providers have also entered the market in large numbers due to growing demand for energy services as well as the high up-front cost of a TANESCO connection. According to a cost comparison of several different energy sources, in 2007 even the least expensive TANESCO tariff level was inaccessible to the

[1] Official and unofficial sources often report divergent electrification numbers. In a report contracted by the government and carried out by Green Max Capital Advisers, for instance, the rural electrification rate was estimated at roughly 7% and the overall, country electrification rate at 21% (Greenmax Capital, 2013).

[2] The "energy ladder hypothesis" suggests that as households become wealthier, they substitute increasingly expensive fuels for one another. Households typically begin with biomass (wood, charcoal), move to kerosene, LPG stoves and eventually electricity. This concept has been widely debated in the literature on fuel switching (Hosier and Dowd, 1987).

rural and urban poor. The initial cost of connecting to the grid was the equivalent of USD $153/household, making electricity an unrealistic option even for those customers who met the geographic and infrastructure criteria for a connection (Malti and Mnenwa, 2014; Green Max Capital, 2013). As a result of existing expansion constraints on the national grid, the off-grid lighting market in Tanzania has been estimated at USD $82 million over the next five years (Green Max Capital, 2013).

Currently, the off-grid energy market in Tanzania is characterized by the presence of government entities, NGOs and private-sector companies targeting various customer segments. Although a number of renewable and non-renewable options exist, photovoltaic (PV) solar is a particularly attractive resource due to rapidly falling PV panel costs and excellent solar insolation (Hammar, 2011). The largest private-sector companies in the Tanzanian off-grid market include SunnyMoney (solar lanterns), EGG-Energy (batteries and solar-home systems), Flexenclosure (customized off-grid power solutions for industrial and commercial customers), and Zara Solar (solar home systems). Although initially focused on high-end and middle-income customers, market participants are increasingly looking for ways to serve clients at the bottom of the pyramid (BOP) clients.

*Off-Grid Electric*

In 2011, OGE was founded with the goal of providing electricity and lighting services to the BOP market in Tanzania. Using the third-party ownership (TPO) model pioneered by American solar providers such as SolarCity, OGE successfully penetrated a low-income market segment with high demand for lighting services but low amounts of capital with which to pay for products and few financing options. In order to make solar affordable for BOP clients, OGE sells solar services instead of solar products by leasing solar home systems (SHS) to their clients. This market segmentation approach, which focuses on pico-scale solar products, is theoretically sound because research in developing markets has shown declining marginal benefit as the size of an SHS increases (Bond, 2011)

The face of OGE in Tanzania is called M-Power, and this company is staffed by a cadre of local agents who work on commission to expand M-Power to new service territories. Once new client signs up for the SHS, it takes an average of 30 minutes to install the system, which consists of a 5 watt panel, a control box, a phone charging mechanism, and either two lights, three lights or three lights and a radio, depending on which price point the customer chooses (Level 1, Level 2 or Level 2+, respectively).

Following installation, clients use M-Pesa, a mobile payment system, to pre-pay for a month of services. Depending on whether they have Level 1 services, Level 2 or Level 2+ services, they either pay

10,400TZH/month, 14,900 TZH/month, or 19,400TZHmonth. In the event of questions or complaints, customers communicate with M-Power via mobile text messages.

*Literature Review*

A meta-analysis of 28 studies that evaluate energy access programs suggests that the impact of electricity on a range of outcomes related to human development remains unclear. In 2014, Maximo Torero of the International Food Policy Research Institute wrote that "the potential positive impacts of rural electrification on development seem to be accepted by consensus in scientific literature" (Torero, 2014). At the same time, most evaluations related to the benefits of electricity "are actually case studies" and do little to isolate the causal impact of specific electrification programs on human development or provide information about the costs and benefits of different approaches to electrification (Torero, 2014).

Existing studies can be divided into two main categories: evaluations of off-grid solar and other initiatives and evaluations of large-scale electrification programs using panel datasets provided by government institutions. Generally speaking, evaluations conducted by NGOs tend to use qualitative methods and provide richer observational data whereas evaluations of grid-based electrification programs employ econometric techniques.

*Evaluations of Off-Grid Solar Technology: Lanterns and SHS*

The NGO evaluations studied as part of this meta-analyses have greatly expanded the types of evaluations that they carry out in the last several years. Whereas in the past studies were limited to focus-group discussions (FGDs) and non-experimental methods, two randomized control trials (RCTs)[3] are currently being conducted by SolarAid and SunnyMoney respectively (SunnyMoney is SolarAid's entrepreneurship arm). The SolarAid RCT on solar lanterns, in particular, is notable because it is the first study to use causal inferences methods in the evaluation of a whole suite of outcomes: poverty alleviation, health, education and others (Harrison, 2015). When completed in the summer of 2015, this study will be the most comprehensive of its kind.

To date, studies of off-grid solar impacts on human development outcomes have yielded mostly positive reviews but employed non-experimental or quasi-experimental methods, which are less reliable than

[3] A randomized control trial randomly assigns individuals into treatment and control groups.

experimental designs.[4] In a study exploring the impacts of solar lanterns on educational outcomes in Tanzania, SolarAid found that lanterns increased study time but also noted significant problems with broken lamps which could not be repaired (Smeets, 2013). Another study in Kenya and Tanzania found that solar lanterns had positive impacts on feelings of self-control among children who could stay up longer and budget their time for studying or play, improved family relationships, decreased rates of respiratory illnesses resulting from kerosene exposure and improved school performance (Esper, 2013). Evaluations of solar lantern impacts in India found that household savings, study time, academic performance and the efficacy with which women could perform household tasks all increased; however, the author provided no evidence to support the latter two assertions (Agoramoorthy, 2009). Although the aforementioned studies provided useful qualitative data, they did not include a control group with which to compare the treatment group and they relied on respondent recall in order to measure changes in study time and gauge improvements in health. The challenges associated with participant recall, particularly among children, have been well-documented in the literature (King, 1981).

Despite the methodological limitations in the aforementioned observational studies, some of the conclusions were supported by studies which employed experimental or quasi-experimental designs. A SolarAid study in Senegal using a (non-randomized) control group found that educational staff perceived improved academic performance as a result of solar lantern use among their students (Harrison, 2013). Furthermore, an RCT in Uganda found that children with lamps studied approximately 30 minutes longer than children in the control group but also found that academic tests scores among solar lantern users decreased (Furukawa, 2013). Another RCT conducted in Kenya found that solar lanterns increased study time and household savings but had no impact on educational outcomes. After observing and testing for evidence of spillover (control group users benefiting from lighting provided by experimental households), the researchers used treatment intensity in classrooms and found that solar lanterns had an impact on math scores (Powering Education, 2014). It should be noted that while these experimental designs were an improvement over earlier methods, researchers continued to rely on subjective participant recall for key indicators (such as improvements in student performance in the Senegal study) as opposed to measuring these indicators directly.

[4] Experimental designs employ causal inference methods to measure the impact of a treatment or intervention on a group of people. They must include a treatment and control group, pre and post-test measurements for the outcome of interest and the random assignment of treatment units (in this case, people or households) into control and experimental groups. Control groups are those who do not get the treatment while experimental groups do. In line with Rubin's causal model, the control group presents a counterfactual for the treatment group: the control group represents what would have theoretically happened to the treatment group if they had not received the treatment. This allows for researchers to estimate the effect of a given treatment.
Quasi-experimental designs are similar to experimental designs, but they lack one of the three elements of an experimental design (treatment and control, pre and posttest or random assignment to treatment and control groups).

Although solar lantern studies provide a starting point for the impacts of energy access on human development, research on SHS is of more immediate relevance to OGE's model. Both of the available impact assessments on SHS systems were non-experimental and relied heavily on participant recall without independent verification of the results. The first study, carried out on Grameen Shakti's SHS initiatives in Bangladesh, found that respondents encountered some challenges in paying for their SHS system (versus kerosene) but perceived a decrease in indoor pollution, an increase in children's study time, improved women's health, an increased range of entertainment opportunities and the ability to work longer at night (Mondal, 2011). The second study, which explored the differences in outcomes between SHS systems with small, medium and large capacity ratings, used participatory rural appraisal techniques to conclude that respondents valued their SHS for increased reading time in the evening and improved efficiency in completing domestic tasks (Bond, 2011).

*Evaluations of Grid-Based Electrification Programs*

Compared to evaluations of distributed energy, impact assessments of rural electrification programs overwhelmingly relied on panel data and econometric techniques. Although expanding the national grid to rural parts of developing countries confers different benefits than distributed energy resources such as lanterns and SHS, impact assessments of electrification nevertheless provide insights into how lighting and charging services impact human development outcomes.

Using a randomized encouragement approach[5] (vouchers), Barron and Torero found that electrification in El Salvador led to significant health improvements, as measured by specially-produced pollution trackers, and positive impacts on education, income and appliance ownership (although, notably, electrification causes no change in highly polluting cooking habits) (2014). Similar studies on the ways in which electrification impacts household-level fuel consumption and decision-making showed mixed results about the ability of electricity to displace polluting and harmful fuels (Thom, 2000; Madubansi and Shackleton, 2005).

Dinkelman, in a widely cited paper, used an instrumental variable approach (land gradient as the instrument) to conclude that electrification in South Africa led to increased female employment but a decrease in female wages (2011). Dinkelman hypothesized that electrification created more jobs, but that those jobs were low-paying, service sector positions. In Nicaragua, electricity was found to increase female employment outside of the home by nearly 23% (Grogan and Adanand, 2012).

[5] A randomized encouragement approach "consists in randomly allocating incentives to connect to the grid, and using them as instruments in an IV estimation" (Barron, 2014).

In a series of studies for The World Bank, Khandker used instrumental variables and a fixed effects approach on panel data from Bangladesh to find significant positive impacts on income, years of schooling completed and poverty reduction (2012). In a similar study on electrification in Vietnam, Khandker found that electrification was associated with increased income and improvements in school enrollment (Khandker, 2009). Van de Walle, in his study on the impacts of electrification in India, challenged the magnitude of Khander's findings and argued that the instrumental variables used in other studies led to an overestimation of the effects of electrification on a host of outcomes. His own study found that village-level electrification increased income in both electrified and non-electrified homes, consumption, the time available to perform work, and had a significant effect on years of schooling for girls (van de Walle, 2013).

The aforementioned econometric studies, while more methodologically rigorous than those available for off-grid technology, often lack the context and richness of the qualitative data gathered in observational studies. Consequently, "there is almost no evidence on the mechanisms that drive the changes" described in econometric studies of electrification (Barron, 2013).

Taken together, many of these studies point to mixed results (Torero, 2014) and a need for further research on both the impacts of energy access and the specific mechanisms through which energy access impact human development indicators.

*Significance of Evaluating OGE*

In 2014, OGE received USD $4.5 million from International Finance Corporation (IFC) to implement the One Million Solar Homes initiative with the Tanzanian government (Meza, 2015). The US Agency for International Development (USAID) has also provided financing totaling more than USD $1 million and international NGOs such as SNV have pioneered results-based financing (RBF)[6] with OGE (SNV, 2015). As large volumes of capital flow from multilateral institutions tasked with reducing poverty to OGE and similar companies, it is imperative to carry out rigorous studies which accurately estimate the impacts of that energy access. Barron summed up the state of impact evaluation in energy access when he wrote that the "massive amounts of resources allocated to rural electrification have usually been justified on the assumed benefits of electrification on health, education, and income, but most of the empirical evidence on which these claims are based is weak" (2014).

[6] Under this model, implementing agencies or companies for energy projects are only paid if the project accomplishes certain pre-determined goals and outcomes.

## *Impact Evaluation Design*

*Outcomes and Research Questions*

As demonstrated by the literature review, energy and lighting access are thought to result in a number of beneficial outcomes. This study will focus on three: lighting consumption, happiness and material well-being. These particular outcomes were chosen as a result of consultations with the client, the time-frame in which the outcomes could be observed (with a maximum six-month window) and the ability of the selected outcome to contribute new findings to the field of energy access.

During initial consultations with OGE, the co-founder expressed interest in learning more about how solar access impacted levels of happiness and overall quality of life among clients. This, in conjunction with the dearth of studies about the relationship between energy access and overall well-being as well as the short time-frame in which this outcome could be expected to occur, led the researchers to pursue this question. Material well-being, on the other hand, has been widely studied in grid expansion evaluations (in the form of income, expenditures and consumption) but not in evaluations of off-grid energy solutions. This factor, along with client interest and a suitable time-frame for observing impacts, led the researchers to pursue material well-being as an outcome. Finally, given mixed results in the literature about the ability of off-grid solutions to displace kerosene, the researchers selected the consumption of lighting services as the third outcome in order to learn more about this aspect of energy access.

Although health and education are frequently mentioned in reference to energy access solutions, these outcomes were explicitly excluded from this study for several reasons. Education will not be addressed due to the tenuous link between study time and educational attainment as well as the difficulties of measuring changes in study habits directly.[7] Health, on the other hand, will not be studied because credible research has already demonstrated the relationship between increased access to clean lighting and decreases in particulate matter exposure (Barron and Manuel, 2014).[8]

Thus, the following research questions will guide this impact assessment:

- Do self-perceived levels of happiness increase as a result of using M-Power's solar product?
- Does the use of M-Power's solar product lead to increases in material well-being?

[7] The key assumption underlying most studies of energy access and time spent studying the evening is that studying longer improves educational outcomes.
[8] Electricity access decreases exposure to PM and reduces acute respiratory diseases if lighting services are used throughout the home (particularly in the kitchen).

- Does the consumption of lighting increase as a result of M-Power's product? If so, does increased use of M-Power lighting services displace traditional fuels?

*Theory of Change (TOC)*

Access to M-Power's services are thought to impact lighting consumption, happiness and material well-being through several mechanisms.

Regarding lighting, access to OGE's services is thought to either entirely or partially displace kerosene, thereby providing a stronger source of lighting for longer periods of time. The theory of change is simple, in that the increased lux results in more access to lighting, although it is not known if customers use M-Power lights for shorter periods of time than they would have used kerosene supplied light.

The theory of change for how access to M-Power's services increases happiness is more complex. Assuming that lack of access to electricity negatively impacts well-being by reducing perceptions of freedom to do what one wishes in the evening, increasing insecurity, curtailing entertainment options and reducing the amount of time that can be spent doing activities with family and friends, then access to lighting may alleviate these short-comings (Esper, 2013). Furthermore, if health problems and accompanying financial difficulties stemming from kerosene result in lowered perceptions of well-being, the displacement of kerosene may improve health and thereby happiness (Barron and Torero, 2014). Furthermore, increased productivity and material well-being may impact perceptions of happiness among M-Power's customers (Khander, 2013; van de Walle, 2013). It should be noted that some of the pathways through which access to lighting is thought to impact happiness depend on assumptions about other outcomes (health, income, etc.).

Like happiness, the link between energy access and material well-being is complex. Access to electricity is thought to increase wealth by providing beneficiaries with new income-generating opportunities, decreasing health-associated expenses, reducing kerosene-associated expenses, decreasing transportation expenses tied to travel for mobile phone charging, improving productivity through improved health, freeing up women's time for new income-generating activities and other pathways. As with happiness, some of the TOC pathways through which energy access impacts wealth depend on assumptions about other outcomes (health, etc.).

*Randomized Control Trial*

In order to determine the impact of OGE's product on lighting access, happiness and material well-being, a randomized control trial (RCT) will be implemented from May to October of 2015. Drawing on OGE's monthly expansion plan, villages with no current OGE presence will be randomly assigned into a treatment and a control group. An RCT was chosen in order to minimize the correlation between the treatment (access to energy) and the outcomes of interest by eliminating selection bias. If the control and experimental groups meet the ignorability condition and are statistically indistinguishable, the researchers will be able to estimate the causal effect of energy access on the three outcomes of interest.

One of the implications of using an RCT design is necessarily withholding energy services from potential M-Power clients for six months. In order to ensure minimal interference with OGE's business model, a phase-in RCT design will be used whereby households in control villages will sign up for M-Power at the same time as those in treatment villages but will only receive services after the completion of the study. They will be informed about this but will also receive compensation following the completion of the study (for both delayed service implementation and time spent answering survey questions). During the course of the study, households in control villages will need to be connected to OGE's information platform so that survey answers can be uniformly collected from households in control and experimental villages.

*Sampling and Sample Size*

This study will employ cluster sampling, with Tanzanian villages (10,000 individuals or less) as the primary sampling unit (PSU) and the household as the secondary sampling unit (SSU). OGE's most recent monthly expansion plan will be used as the sampling frame because the expansion plans are partially based on village and ward-level characteristics which increase the profitability of OGE's activities in that particular location but may also be correlated with happiness and material well-being.

Sample size will be calculated using the UNFCC's technical guidelines (UNFCC, 2012). Appendix A includes a sample equation and calculation. Data on village uptake rates, number of villages served and effect size will be input into the calculation following the pilot study (see below). Currently, there are no accurate estimates for effect size or approximate magnitude of effect size.

*Data Collection Timeline and Protocol*

Using validated indices (see below), data collection will occur in four stages through the use of OGE's data platform and SMS communication between staff and clients.

First, a pilot study will be conducted in May 2015 to check the applicability and accuracy of the chosen indices. The tools will be administered to a sample of 10 household in one village and results will be tabulated. Those who take part in the pilot will be interviewed in order to receive feedback about the process and improve the tools. A key question to be explored during the pilot phase is the extent to which OGE's mobile communication platform is an appropriate tool for administering questionnaires. Since the aforementioned sample size calculation depends on a 100% response rate, response rates will be closely tracked during the pilot in order to make changes to the sample size as needed. Both traditional paper surveys and SMS surveys will be used during the pilot for comparison.

Furthermore, participatory rural appraisal techniques will be used to check the outcomes in this study against the clients' perceived benefits of SHS use (ESMAP, 2003).

After receiving feedback and making the necessary changes, a baseline study will be conducted in June 2015 using either the mobile communication platform or local enumerators who have been trained by the evaluation team. The baseline will be followed by a mid-line survey in August 2015 and an endline survey in November 2015. The final report will be available in February of 2016.

*Indicators*

Of the three outcomes chosen for this study, only lighting can be measured and verified via direct observation. Happiness and material well-being cannot be independently verified by the evaluators and will thus require indicators, or proxies which indirectly measure the outcome of interest. The researchers explored a number of indicators and settled upon those found in the World Values Survey for happiness and the Progress Out of Poverty Index for material well-being.

*Measuring Happiness*

Happiness, fulfillment, well-being and contentment all fall under the umbrella of subjective well-being (SWB), a field of scientific inquiry which can further be subdivided into cognitive and emotional well-being (Helliwell, 2013; Diener, 2003). Cognitive well-being, according to Kahneman, refers to "thoughts that people have about their life when they think about it" and is measured by life evaluations (Kahneman, 2010). Emotional well-being, on the other hand, reflects "the frequency and intensity of experiences of joy, stress, sadness, anger, and affection that make one's life pleasant or unpleasant" (Kahneman, 2010). Although the distinction between the two can become muddled, one way to easily differentiate between a "life satisfaction" and "emotional reports" questions is through the use of words such as "these days," "nowadays," "on the whole," "taking things together" versus "yesterday," "today,"

in relation to how "happy" or "satisfied" an individual thinks they are. According to Helliwell (2013), questions which relate to happiness "in general" or "on the whole" reflect aggregate life circumstances whereas questions with time-specific markers may reflect a mood at a particular point in time as opposed to one's general level of life satisfaction. Consequently, in line with the client's goal of selecting the least-intrusive evaluation method and employing simple indicators, the life evaluation approach as opposed to emotional report approach will be used in this study.

The key assumption underlying this part of the evaluation design is that self-reported measures of happiness are correlated with actual well-being. According to some economists, there is sufficient evidence to conclude that an individual's perceived levels of happiness, as reflected in various indices and surveys, is accurate enough to be meaningfully employed for social science and economic studies (Ferrer-i-Carbonell, 2013). Researchers have tested the validity of these indices by measuring the correlation between self-reported happiness scores and verifiable indicators like facial expressions, smiling, health outcomes, and neural responses (Ferrer-i-Carbonell, 2013; Urry, 2004, Helliwell, 2013).

Although serious work has been done to validate self-reported measures of happiness, Kahneman (2006) points to a number of weaknesses associated with life evaluation surveys including the distortionary impact of external influences (random events which occur prior to the survey, the weather, the actual questions on the survey itself), volatility in answers over short time-scales, and the overall mood of the participants. Despite these drawbacks, he concludes that the aforementioned short-comings are "not necessarily grounds for dismissing the method altogether" due to previously found correlations between SWB measures and what he deems "objective physiological and medical criteria" (Kahneman, 2006).

With these potential limitations in mind, the author examined a range of tools and instruments to gauge happiness in this study including the World Values Survey (WVS),[9] the Gross Happiness Index (GHI),[10] the Gallup World Poll,[11] the European Social Survey,[12] and the European Values Survey,[13] the Oxford Happiness Questionnaire,[14] the Missing Dimensions of Poverty Questionnaire[15] and others. Several questions from the World Values Survey and Gallup World Poll were selected (those which measure emotional state were excluded) for use in this impact assessment (see Appendix B).

[9] http://www.worldvaluessurvey.org/WVSDocumentationWV6.jsp
[10] http://www.grossnationalhappiness.com/docs/2010_Results/PDF/Questionnaire2010.pdf
[11] http://media.gallup.com/dataviz/www/WP_Questions_WHITE.pdf
[12] http://www.europeansocialsurvey.org/docs/round6/fieldwork/source/ESS6_source_main_questionnaire.pdf
[13] http://werteforschung-pt-ktf.univie.ac.at/fileadmin/user_upload/i_pt_ktf_werteforschung/EVS_2008_Questionnaire_English_Original.pdf
[14] http://www.marin.edu/~npsomas/Projects/OxfordHappinessQuestionnaire.pdf
[15] http://www.ophi.org.uk/wp-content/uploads/Psych-subj_survey_website_Dec2011.pdf?aa8b11

*Measuring Material Well-Being*

There are a number of metrics which reflect how an individual's level of material well-being influences their quality of life. Traditionally, income, expenditures and consumption have been used as indicators of wealth (Montgomery, 2000). According to the World Bank (2008), income is "the amount of money received during a period of time in exchange for labor or services, from the sale of goods or property, or as a profit from financial investments," expenditures are "money payments…to obtain goods or services," and consumption is "final use of goods and services, excluding the intermediate use of some goods and services in the production of others." (O'Donnell, 2008). While all three metrics may be useful in high-income nations, material well-being in developing nations is difficult to approximate through income and consumption because individuals often work in the informal sector, employment varies seasonally, monetary transfers comprise income, barter is prevalent and home production often cycles into home consumption (World Bank, 2002).

Given the limitations of traditional metrics, asset-based and other indirect measures of material well-being have been employed to track changes in household-level poverty over time (Vyas, 2006). These proxy indices use readily available household goods, such as radios, televisions or pots and pans, or household characteristics, such as building materials, to approximate a household's material well-being. Although asset-based indices are now commonly employed in demographic and health equality surveys to gauge socio-economic status (SES), one study which used two different asset-based indices in Nigeria found that, despite careful training for the enumerators, the results from the indices did not match one another and changed within short-times frames (Onwujekwe, 2006). Furthermore, USAID-funded study comparing an asset-index with direct-income measurement approaches in Bangladesh, Malawi and Ethiopia concluded that "appreciable mismatch between the two poverty measures could be seen." (Foreit, 2011). Examining a series of studies, Falkingham and Namazie (2002) note that changes in the material well-being or wealth of a household may change in ways which are not reflected by the acquisition of durable goods or changes in household characteristics.

Bolen (2010) argues that despite these shortcomings, an asset-based approach offers more accurate approximations of material well-being because the results can be confirmed by the observations of the enumerator. Additionally, durable goods and particularly household characteristics tend to measure the "stock" of household wealth (a more permanent form of material well-being) than income or consumption, which in developing countries tends to measures fluxes (or flows) in wealth (World Bank, 2008).

Given practical considerations such as simplicity, client preferences for minimal interference in business, and the size of the informal sector in Tanzania, an asset-based versus money-metric approach was selected for this evaluation. A number of indices and tools were studied for inclusion in this evaluation, including the Progress Out of Poverty Index (PPI), the World Bank's Living Standards Measurement Study (LSMS),[16] and the UN's Multidimensional Poverty Index and the idea of a customized Participatory Wealth Ranking.[17] The PPI was selected due to its use throughout the world, relative simplicity (compared to the Living Standards Measurement Index) and the fact that a customized version already exists for Tanzania (see Appendix B).[18]

*Measuring Lighting Consumption*

Of the three outcomes used in this study, the simplest to measure is lighting consumption. One of OGE's goals as a company is to increase customer access to lighting services, which can be gauged by measurements of lux at baseline versus the lux after customers receive OGE's service. Lux, which measures the lumens of light per square meter, is a common metric to gauge the amount and quality of lighting. Using a customized tool which tracks the lumens/area, changes in lighting access can be tracked for OGE customers and control-group households. Furthermore, the use of traditional fuels will be tracked throughout the course of the study in experimental and control households.

*Estimation Strategy*

Using the aforementioned indices as indicators for lighting, happiness and material well-being, the researchers will estimate the causal impact of energy services on the outcomes of interest through a two-step process.

First, in order to ensure that the randomization resulted in control and treatment groups that are statistically similar in terms of observable characteristics, a T-test will be run on observable characteristics which are correlated with the outcomes being studied. In this case, since OGE's monthly expansion plans will be used as the sampling frame, the T-test will be run on the variables according to which villages are selected for expansion (which are also correlated with high uptake of M-Power). Since expansion plans were crafted to include those clients who are in OGE's optimal income bracket (a

[16] http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/EXTLSMS/0,,contentMDK:23636522~pagePK:64168445~piPK:64168309~theSitePK:3358997,00.html

[17] http://siteresources.worldbank.org/EXTTOPPSISOU/Resources/1424002-1185304794278/4026035-1185375653056/4028835-1185375678936/5_Wealth_ranking.pdf

[18] It should be noted, however, that the PPI may need to be altered (in consultation with the designer of the tool) in order to account for the presence of items such as radios and lanterns in the inventory.

relatively high income bracket within the BOP segment), the same variables which influence OGE's ability to expand into a new area are partially correlated with factors such as material well-being and happiness. These observable characteristics include land cultivation (a function of high annual rainfall and low land elevation), access to both primary and secondary roadways, peri-urban and high-density areas, and residential structures with metal roofs (Eastling, 2015). Once the control and experimental groups are compared according to these variables, the researchers can determine the extent to which the randomization process succeeded in eliminating differences between the two groups.

In the second part of the study, three separate regressions will be run for each of the outcomes of interest (one for each outcome of interest). The equations are as follows:

$$Happines\ Index\ Score = \alpha + \beta OGE + \varepsilon$$

$$Material\ well-being\ Index\ Score = \alpha + \beta OGE + \varepsilon$$

$$Lighting\ Consumption = \alpha + \beta OGE + \varepsilon$$

However, given the possibility that randomization may not eliminate variables which are correlated with income, happiness and lighting consumption, the researchers will also run a regressions which controls for these variables by including them in the equation.

*Conclusion*

As OGE continues to expand, identifying the social and economic impacts of lighting services on the rural poor will become increasingly important. Using the evaluation plan presented in this report, OGE will be able to evaluate how M-Power impacts levels of happiness, material well-being and lighting among its customer base. Once carried out, these evaluations can be utilized for future fundraising among key investors and to meet donor evaluation requirements.

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Appendix A: Sample Size Calculations and Explanation

$$c \geq \frac{1.96MV^2}{(M-1) \times 0.05^2 + 1.96V^2}$$

In the aforementioned equation:

$$V = \left(\frac{SD}{Cluster\ Mean}\right)^2$$

$$M = total\ population\ of\ villages\ being\ served\ by\ OGE$$

$$1.96 = 95\%\ confidence\ required$$

$$0.05 = required\ precision$$

Appendix B: Sample Questions from English version of World Values Survey and PPI questionnaire for Tanzania

World Values Survey Questions, South Africa Sample, 2013:

| V23. | ASK ALL; OMO SHOWCARD XX<br>All things considered, how satisfied are you with your **life as a whole** these days? Using a scale where 1 means you are "completely dissatisfied" and 10 means you are "completely satisfied" where would you put your satisfaction with your life as a whole? | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| COMPLETELY DISSATISFIED | | | | | | | | | COMPLETELY SATISFIED |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

*Figure 1 Sample life satisfaction question from World Values Survey. Source: http://www.worldvaluessurvey.org/WVSDocumentationWV6.jsp*

| V55. | ASK ALL; OMO SHOWCARD XX<br>Some people feel they have complete free choice and control over their lives, while other people feel that what they do has no real effect on what happens to them. Please use this scale where 1 means "no choice at all" and 10 means "a great deal of choice" to indicate how much freedom of choice and control you feel you have over the way your life turns out. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| NO CHOICE AT ALL | | | | | | | | | A GREAT DEAL OF CHOICE |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

*Figure 2 Sample life satisfaction question from World Values Survey. Source: http://www.worldvaluessurvey.org/WVSDocumentationWV6.jsp*

| V59. | ASK ALL; OMO SHOWCARD XX<br>How satisfied are you with the financial situation of your household? Please use this card to help with your answer. One means you are completely dissatisfied and 10 means you are completely satisfied. If your views fall somewhere in between you may choose any number in between. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| COMPLETELY DISSATISFIED | | | | | | | | | COMPLETELY SATISFIED |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

*Figure 3 Sample life satisfaction question from World Values Survey. Source: http://www.worldvaluessurvey.org/WVSDocumentationWV6.jsp*

Gallup World Poll Sample Questions:

All things considered, how satisfied are you with your life as a whole these days? Use a 0 to 10 scale, where 0 is dissatisfied and 10 is satisfied.

*Figure 4 Gallup World Poll life satisfaction sample question, source: http://media.gallup.com/dataviz/www/WP_Questions_WHITE.pdf*

Please imagine a ladder with steps numbered from 0 at the bottom to 10 at the top. Suppose we say that the top of the ladder represents the best possible life for you and the bottom of the ladder represents the wors possible life for you. On which step of the ladder would you say you personally feel you stand at this time, assuming that the higher the step the better you feel about your life, and the lower the step the worse you feel about it? Which step comes closest to the way you feel?

*Figure 5 Gallup World Poll life satisfaction sample question, source: http://media.gallup.com/dataviz/www/WP_Questions_WHITE.pdf*

Progress Out of Poverty Index, Tanzania:

| Indicator | Value | Points | Score |
|---|---|---|---|
| 1. How many household members are 17-years-old or younger? | A. Four or more | 0 | |
| | B. Three | 10 | |
| | C. Two | 15 | |
| | D. One | 20 | |
| | E. None | 30 | |
| 2. Do all children ages 6 to 17 attend school? | A. No | 0 | |
| | B. Yes, or no children ages 6 to 17 | 3 | |
| 3. Can the female head/spouse read and write? | A. No | 0 | |
| | B. Yes, but not in Kiswahili nor English | 0 | |
| | C. No female head/spouse | 0 | |
| | D. Yes, only in Kiswahili | 6 | |
| | E. Yes, in English (regardless of others) | 13 | |
| 4. What is the main building material of the floor of the main dwelling? | A. Earth | 0 | |
| | B. Concrete, cement, tiles, timber, or other | 11 | |
| 5. What is the main building material of the roof of the main dwelling? | A. Mud and grass | 0 | |
| | B. Grass, leaves, bamboo | 8 | |
| | C. Concrete, cement, metal sheets (GCI), asbestos sheets, tiles, or other | 9 | |
| 6. How many bicycles, mopeds, motorcycles, tractors, or motor vehicles does your household own? | A. None | 0 | |
| | B. One | 3 | |
| | C. Two or more | 11 | |
| 7. Does your household own any radios or radio cassettes? | A. No | 0 | |
| | B. Yes | 6 | |
| 8. Does your household own any lanterns? | A. No | 0 | |
| | B. Yes | 6 | |
| 9. Does your household own any irons (charcoal or electric)? | A. No | 0 | |
| | B. Yes | 5 | |
| 10. How many tables does your household own? | A. None | 0 | |
| | B. One | 2 | |
| | C. Two | 4 | |
| | D. Three or more | 6 | |
| By Mark Schreiner of Microfinance Risk and Management L.L.C, developer of the PPI | Total score: | | |

*Figure 6 Progress Out of Poverty Index, Tanzania, Source: Mark Schreiner, http://www.progressoutofpoverty.org/country/tanzania*

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