Rural Renewable Energy Project (RREP) in Sierra Leone

Baseline Report for the conduct of the Impact Evaluation

(Work Package 1 & 1+)

September 2019

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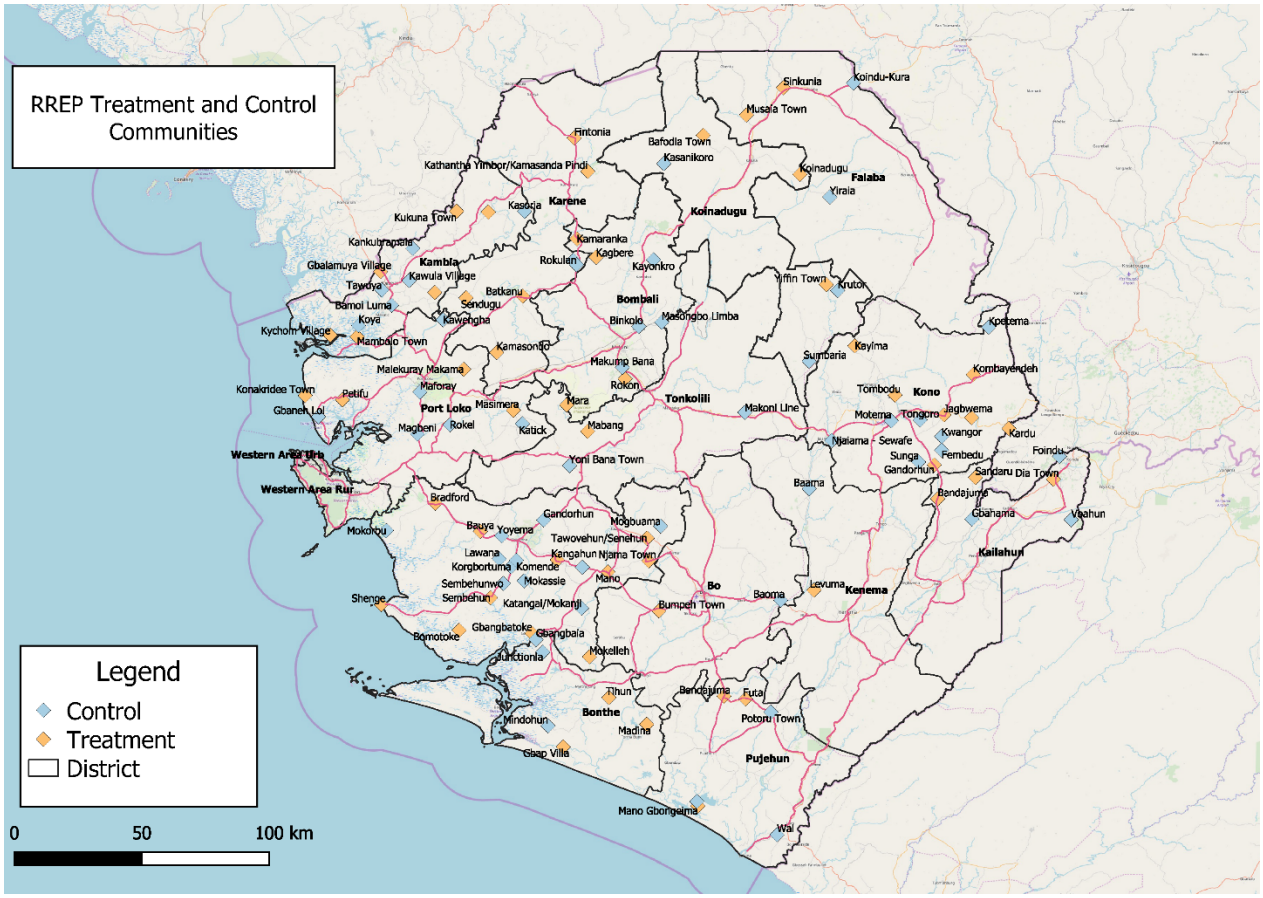
List of Acronyms

CHC	Community Health Centre
DAC	Development Assistance Committee
DfID	Department for International Development
DHMT	District Health Management Team
DMO	District Medical Officer
EMIS	Education Management Information System
ENFO	Energy for Opportunity
ESMAP	Energy Sector Management Assistance Programme
EWRC	Electricity & Water Regulatory Commission
FGD	Focus Group Discussion
FQSE	Free Quality School Education
GoSL	Government of Sierra Leone
GST	Government Sales Tax
KII	Key Information Interview
kWP	Kilowattpeak
MoE	Ministry of Energy
MCC	Millennium Challenge Corporation
MoHS	Ministry of Health and Sanitation
M&E	Monitoring and Evaluation
MTNDP	Medium Term National Development Plan 2020-2023
OECD	Organisation for Economic Co-operation and Development
PI	Principal Investigator
RE	Renewable Energy
RBF	Results Based Finance
RREP	Rural Renewable Energy Project
SEC	Social Sciences Ethics Committee
SLESRC	Government of Sierra Leone Ethics and Scientific Review Committee (SLESRC)
SLL	Sierra Leonean Leone
SLPP	Sierra Leone People's Party
sPV	Solar Photovoltaic
ToC	Theory of Change
UNOPS	United Nations Office for Project Service
WHH	Welthungerhilfe
WP	Work Package
WUR	Wageningen University and Research

Treatment and Control Sites



Executive Summary

The United Nations Office for Project Services (UNOPS) is supporting the Government of Sierra Leone's (GoSL) goal of universal access to electricity by implementing the US$40+ million Rural Renewable Energy Project (RREP). RREP – funded by the UK Department for International Development (DfID) – is an ambitious electrification project that will provide access to off-grid solar electricity to up to 94 communities in Sierra Leone by 2020.

Sierra Leone is one of the world's poorest countries, ranking 179th out of 188 countries in the Human Development Index in 2016. In Sierra Leone, only 2.5 percent of the population in rural areas have access to electricity. Poor access to electricity is recognised as a binding constraint to long-term economic growth in Sierra Leone.

RREP is expected to improve Sierra Leone's economic development through an increase in access to rural energy resources. Increased access to sustainable energy is expected to increase welfare in rural communities by improving income, health, and education and lowering fuel expenses and Green House Gas emissions.

This Baseline Report is the first part of the RREP Impact Evaluation to quantify the effects of the UNOPS intervention by gathering and analysing primary and secondary data sources in light of the project logframe and Theory of Change. To understand the impact of mini-grids, we will look at the following four "Impact Domains", as advised in the project design documents.

1. Does increased access to electricity increase incomes and assets?
2. Does increased access to electricity improve the health conditions?
3. Does increased access to electricity increase school attendance?
4. Does increased access to electricity reduce CO_2e emission?

The evaluation strategy compares a representative sample of households in communities where mini-grids were installed as part of RREP with a representative sample of households in similar communities where no mini-grid was installed. Health centres in RREP communities were electrified before the baseline survey was conducted, but households did obtain access to electricity until after the baseline survey. We discuss potential biases from the pre-survey electrification of health centres and find these biases to be likely small and surmountable with analysis of secondary data from health centres. While households from communities where RREP was implemented are largely similar to households in communities that are used as comparison communities, important differences are present at baseline. For example, RREP communities have higher levels of certain wealth indicators, such as total livestock ownership and ownership of electrified assets. As detailed in the report, we find it likely these differences are pre-existing at baseline, rather than brought on by RREP. We use a difference in difference estimation strategy that accounts for these pre-existing differences.

Several findings from the baseline data stand out:

Income and Assets

Most households grow staple crops at subsistence levels, as opposed to higher valued cash crops. Out of the households surveyed, 54 percent grow rice and 27 percent grow cassava. Comparatively the proportion of households who grow cocoa is 8 percent, and an even lower proportion grow coffee, at 4 percent. Out of those growing staple crops, less than 10 percent of the rice harvested is sold at market, and roughly half of cassava produced is sold at market. Agricultural production is not statistically different

between treatment and control sites in most cases. The exception is cassava production. Those in the control group sow more heaps of cassava (116 heaps vs. 57 heaps), and harvest more kgs of cassava (242 kgs vs. 174 kgs.), compared to those in the treatment group. This difference is statistically significant. 116 57are in largely similar acronot statistically different with the exception of heaps of cassava sowed and kilograms of cassava harvested. Households in the control group sow 59 more heaps, and harvest 67 kgs more of cassava.

Households working in the non-agricultural sector are more likely to be self-employed rather than hired by an organization. About one-third of the sample (31 percent) are self-employed, the most prevalent of which are low-earning traders. Telecentres, construction workers, and taxi drivers are the most lucrative, but only make up 10 percent of self-employed. Only 9 percent are employed by an organization and make a salary. Households in treatment sites are more likely to be self-employed compared to control (35 percent vs 26 percent) and employed by an organization (9.5 percent vs 5.8 percent). However, we find that earnings are not statistically different between the two groups.

Livestock ownership is high, but most animals owned are of low value. Nearly 60 percent of households own chickens (a low value animal), while only 4 percent own cows, the highest value livestock. Treatment communities have on average one more animal per household than control communities; this difference is statistically significant.

There is little ownership of productivity enhancing electrified assets, such as freezer (2.9 percent), sewing machine (2.4 percent) and electric stove (0.15 percent). Of our full sample, the most commonly owned electrified assets are for communication (phone 54 percent) and entertainment (DVD equipment 9 percent, televisions 7 percent, and stereo 3 percent). We do find that ownership of freezers is higher in the treatment group compared to the control group (4 percent vs 1.6 percent). Ownership of mobile phones is also 14.5 percentage points higher in the treatment group compared to the control group (61 percent vs. 46.5 percent). These differences are statistically significant.

Health Conditions

Many respondents in the sample reported suffering from acute respiratory infection (ARI), and malaria in the 30 days prior to being interviewed (22 percent and 41 percent respectively). More women reported suffering from malaria in the past month than men. Children are more heavily impacted by ARI. Around 30 percent of children under the age of 5 suffered from ARI compared to 17.5 percent of those over 5.

Health seeking behaviour for those suffering from malaria and ARI is modest. Half of those suffering from malaria-like symptoms sought treatment at the community health centre. For those who suffered from ARI-like symptoms, 33 percent sought treatment at the community health centre. There are no statistically significant differences between treatment and control sites in any of these health indicators.

In line with existing data, maternal and child mortality rates are frighteningly high. 2 percent of households that reported a pregnancy in the past year reported that a woman died during pregnancy or delivery over the past year. 5 percent of households with at least 1 pregnancy in the past year experience at least 1 stillbirth.

Education

Enrolment rates and attendance rates are high in our sample. Eighty-nine percent of sampled school age children are enrolled in school, with around 88 percent not missing a day of school in the past week. 8.5 percent report missing school 1 to 2 days in the past week. Students in the treatment groups are more

likely to be enrolled (90.8%) compared to control groups (88.2%) and are less likely to have missed a day in school in the past week (30.5 percent vs. 23.9 percent). However, neither of these differences are statistically significant.

Children spend on average 7.5 hours each week studying at home, or a little more than an hour each day. Children spend more time studying in a week compared to other time uses such as household chores (7 hours), and farm work (3.6 hours). School age children in treatment groups study on average 1.23 more hours compared to children in control groups (8.3 hours vs. 7 hours). This difference is statistically significant.

CO2e Emissions

There is much room for reduction of CO2 emissions through changes to household appliances. Over 99 percent of households use wood/charcoal as either a primary or secondary source of cooking energy. When broken down, 77 percent of households get their primary or secondary source of cooking energy from collected firewood, while another 14 percent purchase firewood, and nearly 18 percent purchase charcoal. Few households at baseline are using electric stoves. Rates of household ownership of electric stoves hover near zero at .1% - .2%. There is no statistically significant difference between electric stove ownership in treatment and control communities.

Gender Equality

Gender differences were striking for respondents who classified themselves as self-employed outside of agriculture. The mean profit for men is about 469,000 SLL per month. Women report a profit of 184,800 SLL per month, significantly less than men. This earnings gap can be explained by differences in occupations. For instance, we find that women are more likely to work in low earning occupations such as petty trading (62%) compared to men (24%).

In terms of health, more women reported suffering from malaria in the past month than men. However, women more likely to seek treatment for their illness compared to men.

There are no statistically significant differences in school enrolment rates or attendance rates between boys and girls. However, we do find that boys are reported to study more than girls and this difference is statistically significant. Girls are found to spend more time each week doing household chores compared to boys. This difference in time spent on household chores could be driving the gender gap in study time.

Disability

Of the 7,846 respondents surveyed, 2 percent report having difficulty hearing, remembering, or with self-control. 8 percent of respondents report difficulty seeing, and 6 percent report difficulty walking. Overall, 15 percent of individuals report having at least one disability (note that each individual can suffer from more than one disability). More women (6.6 percent) have a disability related to mobility and walking compared to men (5.1 percent).

Recommendations

The report concludes with four recommendations targeted at both policy makers and UNOPS. These recommendations aim to enhance program adaptivity and relevance. Detailed recommendations will follow in the mid-term and final evaluation reports. Our first three recommendations are based on our two central findings of baseline survey: 1) while many individuals are investing substantial amounts of time in self-employment activities, on average self-employment is not very profitable; 2) there appears to be few outside employment options.

Recommendation 1: Policy interventions that increase the adoption of productive electrified assets should be developed and rigorously tested.

Recommendation 2: Policy interventions that support private sector development should be developed and rigorously tested.

Recommendation 3: The welfare benefits of policy interventions that a) support the adoption of productive technologies and b) support private sector development should be rigorously measured.
Our fourth recommendation is based on findings from focus group discussions.

Recommendation 4: UNOPS could improve communication with local authorities and beneficiaries residing in communities where mini-grids have been installed. In particular, it could be useful to verify whether local authorities have properly understood relevant messages and pass them along correctly to the local population.

Section 1: Introduction

1.1 Background to The Rural Renewable Energy Project

In an effort to support the Government of Sierra Leone (GoSL) towards universal access to electricity, the United Nations Office for Project Services (UNOPS) is implementing the US$40+ million Rural Renewable Energy Project (RREP), an ambitious electrification project that will provide access to off-grid solar electricity to up to 94 communities in Sierra Leone by 2020. The RREP targeted large rural towns (often chiefdom headquarter towns) throughout the country that are regional focal points for economic and social life. The RREP is funded by the UK Department for International Development (DfID) and implemented in collaboration with the GoSL Ministry of Energy and UNOPS.

The provision of off-grid solar electricity will take place in different phases. In phase 1 of the project (Work Package 1), 54 community health centres across the country were provided electricity. In the next phase (Work Package 1+), 50 solar mini-grids have been set up in 50 communities across different districts of the country. In Work Package 2, 44 additional mini-grids will be set up and managed by private sector operators. It is anticipated that Work Package 1+ and Work Package 2 will lead to more households becoming connected to electricity.

There are currently three private sector operators involved in the RREP, brought in through a competitive international tender for operations and maintenance of the 50 existing sites; and to operate, maintain and co-invest in 44 additional, larger mini-grids. The sites have been split into four geographical lots, with Off-Grid Power awarded two; Winch Energy awarded one; and Energiciti (a subsidiary of Ghana-based Blackstar) awarded one. Off Grid Power has since been bought by PowerGen, who also head the African Mini-Grid Association. The operators are now in the process of finalizing their debt and equity financing, mobilizing in country, and going through site handover processes.

While the Impact Evaluation focuses only on Work Packages 1/1+ and 2, there are four remaining Work Packages: Work Package 3 focuses on providing technical capacity building to government and private sector partners; Work Package 4 was an amendment to the initial contract to support the response to landslide and flooding; Work Package 5 focuses primarily on monitoring and evaluation; and Work Package 6 is focused on private sector engagement and strengthening to promote use economies in mini-grid catchment areas.

The expected impact of the project is that it will improve Sierra Leone's economic development through an increase in access to rural energy resources. In doing so it expects to increase the welfare in rural communities in terms of saved fuel costs, improved income, improved health and education outcomes, and lower Green House Gas emissions. The project intends to enhance, in an integrated way, energy security, business start-ups, reduction of local pollution and improvement of the livelihoods and living conditions of the local communities, with special attention to vulnerable groups, including women and young people.

The overall outcome of the project is improved rural renewable energy access through private sector involvement. It is estimated that approximately 100,000 direct beneficiaries in rural Sierra Leone will be connected to electricity, with a further 480,000 indirectly benefitting from access to low carbon electricity

over the 48 months project lifetime. More than half a million Sierra Leoneans living in remote and rural areas will benefit overall from the project and will be provided with universal access to electricity.

1.2 Country Context

Sierra Leone is one of the world's poorest countries, ranking 179th out of 188 countries in the Human Development Index in 2016.[1] Poverty is widespread with more than 53 percent of the population living below the national poverty line.[2] The country has an increasingly young population, with about 42 percent of the population aged under 15. Youth unemployment is also high, at 60 percent.

The new Government has made education a top priority for the country. President Maada Bio's Sierra Leone People's Party (SLPP) manifesto prioritises the Free Quality School Education (FQSE) initiative, launched in August 2018. The FQSE aims to provide free education to 1.5 million children in Government and Government-assisted.[3]

Health outcomes in Sierra Leone are poor. A critical shortage of skilled health personnel is compounded by the majority of health workers working in urban areas (for example, 40 percent of all midwives serve in Freetown). Maternal mortality is the highest in the world with 1,360 deaths per 100,000 live births, caused primarily by preventable causes. Sierra Leone also has the 4th highest under-five mortality rate in the world, again with the majority of these deaths a result of easily preventable causes.[4]

Multidimensional child poverty rates are high in Sierra Leone, with 8 out of every 10-children deprived in at least one dimension. The Gini coefficient stands at 35.4.[5] Over seventy percent of Sierra Leonean children are poor, suffering a violation of at least one of their basic rights. Rural areas have a higher incidence of child poverty than urban areas.[6]

In Sierra Leone, only 2.5 percent of the population in rural areas have access to electricity.[7] Poor access to electricity is recognised as a binding constraint to long-term economic growth in Sierra Leone[8]. Policy makers, donors, and international development organisations have made universal access to electricity a priority in Sierra Leone as a result.

The Government's Medium-Term National Development Plan 2019-2023 (MTNDP) outlines its key policies for the next four years.[9] By 2023 the Government plans to:

1. Embark on increasing electricity generation, transmission, and distribution.
2. Improve on the policy and regulatory environment of the energy sector.
3. Restore electricity supply to all district headquarter towns and cities.

[1] http://hdr.undp.org/sites/default/files/2016_human_development_report.pdf
[2] http://databank.worldbank.org/data/views/reports/reportwidget.aspx?Report_Name=CountryProfile&Id=b450fd57&tbar=y&dd=y&inf=n&zm=n&country=SLE
[3] The New Direction
[4] UNICEF Situation Analysis 2019
[5] http://hdr.undp.org/en/content/income-gini-coefficient
[6] UNICEF Situation Analysis 2019
[7] World Bank SE4ALL
[8] Rural Renewable Energy Project Brief, UNOPS, 2018
[9] Medium Term National Development Plan 2020-2023, GoSL, 2019

4. Increase investment in low-cost renewable energy (solar, hydro, wind, and biomass) production and distribution.
5. Improve governance at all levels of the sector – the Ministry of Energy, the Electricity Distribution and Supply Authority, the Electricity Generation and Transmission Company, and the Electricity and Water Regulatory Commission – to develop responsible leadership and institutional culture.
6. Ensure expansion of the transmission grid nationwide by increasing the annual regular kilometric coverage.
7. Ensure rural electrification is carried out through engagement and involvement of key stakeholders, including the private sector.

The GoSL approved in 2019 the Electricity & Water Regulatory Commission's (EWRC) mini-grid regulations. This has provided clarity on licensing, grid arrival and the tariff formula for mini-grid operators and indicates a long-term commitment to the sector. GoSL is agreeing tariffs and contracting processes with the three operators based on the mini-grid code in the regulations. There is also extension of tax incentives as part of a wider commitment to the off-grid sector in the Finance Act, which includes provisions for a duty waiver and Government Sales Tax (GST) extension.

The Ministry of Energy is undertaking a Multi-Tier Framework survey to provide data on energy consumption (including mini-grids).

Three other grids have been constructed in Sierra Leone by Welthungerhilfe (WHH), with funds from the European Union, plus one constructed by Energy for Opportunity (ENFO), funded by the Economic Community for West African States' (ECOWAS) Centre for Renewable Energy and Energy Efficiency.

A number of other organisations are looking at market entry in Sierra Leone, including Cross Boundary Energy and Power Corner. Several are leveraging scale up opportunities in the region. For example, the Millennium Challenge Corporation's (MCC) Results Based Finance (RBF) programme is funding 40 mini-grids with 8 new companies in Benin. Some of these organisations are looking closely at growth opportunities in Sierra Leone.

1.3 Impact Evaluation of the RREP

This Baseline Report is the first part of the RREP Impact Evaluation to quantify the effects of the UNOPS RREP intervention in Sierra Leone by gathering and analysing primary and secondary data sources. The evaluation strategy compares beneficiary households in communities where mini-grids were installed as part of RREP with households in similar communities where no mini-grid was installed. While mini-grids were already constructed in WP1 RREP communities before the Impact Evaluation commenced, households did not yet have access to electricity. The Impact Evaluation will generate lessons and recommendations that can be used in the design and implementation of similar interventions in Sierra Leone and elsewhere in the world.

The Impact Evaluation will also assess the Value for Money of different mini-grid interventions; whether the respective projects have been efficiently implemented; and whether the interventions were, as a whole, worthwhile. This will enable the IE report's end-users to:

a. Build the evidence base for further off-grid rural electrification projects across the African continent and beyond
b. Build the evidence base for a model for public-private partnership in rural renewable energy provision
c. Report to beneficiaries, stakeholders and donor on what has been achieved through the project life.

The primary evaluation question of the Impact Evaluations is: What is the impact of mini-grids installed in WP1/1+ and WP2 as part of RREP? To understand the impact, we will look at the following four "Impact Domains".

1. Does increased access to electricity increase incomes and assets?
2. Does increased access to electricity improve the health conditions?
3. Does increased access to electricity increase school attendance?
4. Does increased access to electricity reduce CO_2e emission?

In addition, the impact evaluation will investigate the effects of RREP on different gender and disability groups and ages. It will assess whether there are unintended positive or negative consequences of electrifying rural communities through solar mini grids; and how the effects of electrification change over time.

Table 1: Timeline of Key Evaluation Activities

Key Evaluation Activity	Key Timelines
1. Baseline WP1/1+	
Develop methodology	*March – April 2019*
Design sampling	*April – May 2019*
Deliver inception report	*May 2019*
Data collection	*June – July 2019*
Deliver baseline report	*August 2019*
2. Baseline WP2	
Develop methodology	*September 2019*
Design sampling	*September 2019*
Deliver inception report	*September 2019*
Data collection	*October - November 2019*
Deliver baseline report	*December 2019*
3. Midterm WP1/1+	
Deliver inception report	*April 2020*
Data collection	*April 2020*
Deliver midterm assessment	*June 2020*
4. Endline	
Deliver inception report	*February 2021*
Data collection	*February – March 2021*
Deliver midterm assessment	*June 2021*

The Impact Evaluation will follow the Organisation for Economic Co-operation and Development's (OECD) Development Assistance Committee's (DAC) criteria and its standards for evaluating development

assistance.[10] Specifically the Impact Evaluation will look at the relevance, effectiveness, efficiency, impact and sustainability of the RREP's intervention, specifically related to its intended impact using a quasi-experimental evaluation design.

The Impact Evaluation will evaluate the theory of change's (ToC) impact and outcomes. It will focus solely on the medium-term impact of increased access to electricity on individuals and households.

1.4 RREP Theory of Change

Figure 1 shows the ToC of the mini-grids created under RREP, describing the mechanisms through which access to electricity is expected to impact the desired outcomes. The theory of change describes *how* the inputs of the project are expected to lead to improved outcomes and, ultimately, positively impact the targeted population.

The different components of the theory of change are:

- **Challenges**: Sierra Leone faces key development challenges relates to low access to energy and underdevelopment
- **Inputs**: resources invested in the construction of mini-grids as part of RREP
- **Outputs**: specific realizations of the programme. In what way were resources deployed?
- **Outcomes**: expected changes to key indicators as a result of the construction of mini-grids. Outcomes explain how outputs can lead to the desired impact.
- **Impact**: Medium term (2 year) effects of mini-grids on impact indicators. Used to determine if the programme meets its objectives.

While the intended impact has been described above, below are the RREP's outputs, outcomes and assumptions.

1.4.1 Outputs

1) Electrification of Community Health Centres (CHC) and extension of the mini-grids to households communities (WP-1 and WP-2). This provides access to reliable electricity to rural areas that otherwise are unpowered.
2) Private sector invests, operates and maintains generation and distribution equipment. Mini-grids are operated by private sector contractors. This leads to private sector engagement in investments, operations, and maintenance of the generation and distribution equipment.
3) Improved environment to support private sector investment, and commercial sustainability of off-grid electricity provision.
4) Increased demand for electricity provided through stimulation of private sector development. This sparks interest for private firms to explore business opportunities in rural areas.

[10] https://www.oecd.org/dac/evaluation/daccriteriaforevaluatingdevelopmentassistance.htm

1.4.2 Outcome

The evaluation team will collect information needed to assess the outcomes based on key outcome indicators. RREP outcome target: *"360,000 people (50 percent females) in rural Sierra Leone will directly benefit from access to low carbon electricity. Baseline value will be established which will be compared with the endline through the survey and triangulated through project reports and reports from the private sector energy suppliers."*

1.4.3 Assumptions

A key area to examine over the course of the IE are the underlying assumptions of the ToC. The ToC assumes that the following will take place over the course of the project:

Output Level Assumptions

- CHCs will operate for longer hours following access to electricity
- Households are willing to pay
- GoSL remains committed to the intervention
- Private companies become interested in investing in rural areas due to increased opportunities
- Operations and maintenance are sufficient for effective supply
- Demand does not affect the stability of the mini-grids

Outcome Level Assumptions

- Households and businesses will choose to connect to the mini-grids
- There will be up to 1.8m indirect beneficiaries
- Vulnerable households are not discriminated against
- Women and girls benefit from increased access to electricity as much as men and boys

Impact Level Assumptions

- *Time saved through electrification will be spent on income generating activities by women and men*
- *Electrical appliances yield better results than non-electrical appliances*
- *Students will use the extra time they have available to study*
- *Households value renewable energy over fossil fuels*

These impact level assumptions will be considered across the IE at baseline, midterm, and endline research instruments. Understanding whether these assumptions are correct, particularly the attitudes and behaviours around how individuals use time saved as a result of access to electricity, will be critical to assessing the impact of the RREP.

1.4.4 Key Stakeholders

The key stakeholders and end users of this report include the Government of Sierra Leone, in particular the MoE and Ministry of Health and Sanitation (MoHS); development projects in Sierra Leone and sub-

Saharan Africa; policy actors in Sierra Leone and sub-Saharan Africa; private sector solar operators; academics and research institutions; and consumers. (See Annex D for a full list of stakeholders.)

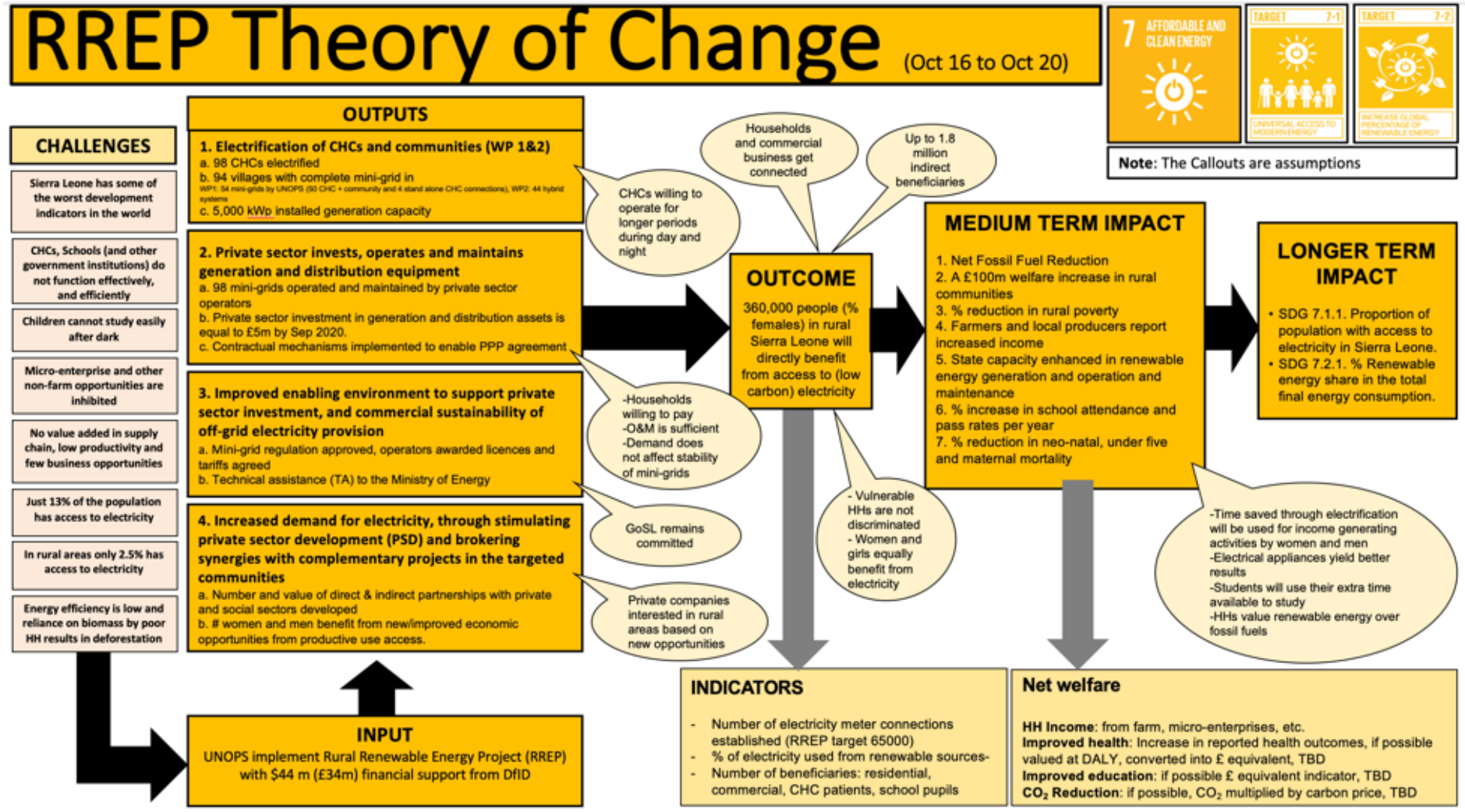


Figure 1: RREP Theory of Change

1.5 Governance of Baseline

UNOPS leads on the design and management of the baseline study for the impact evaluation of the RREP. UNOPS appointed Wageningen University and Research (WUR) and its partners, including Yale University and the International Growth Centre (IGC) for deliverables such as a baseline report for the RREP, summary factsheets and infographics amongst others.

UNOPS also engaged the M&E department of the Ministry of Energy in Sierra Leone as one of the key stakeholders to the design and conduct of the baseline study for the RREP. Throughout the Impact Evaluation process to date the Government has been engaged and its recommendations included in the evaluation approach. The Project Board is regularly updated on all the activities under the M&E workstream of the project.

Table 2: Overview of Baseline Governance

Partner Name	Roles and responsibilities
Wageningen University and Research (WUR)	WUR is the evaluation manager for this impact evaluation. The WUR team is led by Maarten Voors, Research Coordinator. It employs several key personnel, including the Research Coordinator, the Research Associate, the Qualitative Researcher, Field Manager, Field Coordinator, and Enumerators. WUR is responsible for the following activities: - Designing and delivering the evaluation strategy - Training interviewers and piloting research tools - Analysis for primary data and reporting - Data collection, processing and cleaning - Secondary data collection - Sharing key findings and lessons learned - Quality assurance and data quality - Validation workshops
Yale University	Yale University is responsible for designing and developing the data collection tools, an evaluation design, as well as providing guidance to all team members on research methodology and implementation. It will also lead on data analysis and cleaning. Yale University contributions are overseen by the Team Leader, Mushfiq Mobarak. Yale University is responsible for the following activities: - Development and finalization of data collection tools - Evaluation design - Training of enumerators - Analysis of all baseline, mid-term and endline data - Support with reporting - Data cleaning - Development of infographics

International Growth Centre (IGC)	IGC is responsible for providing the Research Manager to oversee research design. The Research Manager, Niccolo Meriggi, will be based full-time in Sierra Leone. IGC is responsible for: - Inputs into research design, methodology, data collection tools. - Data analysis from a local context - Facilitate building the evidence base for maximum policy impact. - Liaise with stakeholders (e.g., GoSL, UNOPS, DFID, Inensus), and between Key Personnel and field teams.

1.6 Purpose of Baseline

The baseline report is the first of three processes of the impact evaluation that comprise the Impact Evaluation of the mini-grids intervention of RREP. The purpose of the Impact Evaluation is to estimate the effects of the mini-grids on community welfare and development. Specifically, WUR will evaluate socio-economic impacts across four key domains:

- Income and Assets
- Health Outcomes
- Education Outcomes
- CO_2(e) Reductions

The baseline data collection measures the target population's current socio-economic status across those four key domains, prior to the intervention. The baseline data will then be compared against the mid- and end-line research to assess the medium-term impacts of the RREP's mini-grids. For a detailed overview of the methodology see Section 2.

This baseline report focuses on UNOPS Work Package (WP) 1/1+. This work package installed stand-alone solar photovoltaic (sPV) systems in 54 communities. Initially the sPV systems were providing electricity to only the respective communities' Community Health Centres (CHCs). These were subsequently expanded into small mini-grids in 50 villages and connected all other public institutions and households in the villages. The 50 small mini-grids will be operated by private operators with commercial interests in a bid to provide sustainable access to electricity to community members. The baseline has taken place before the electricity access was provided to the households and businesses to enable us to track household and individual level changes following access to electricity.

The baseline findings are analysed in this report, and disseminated to stakeholders for insight into what changes could take place in communities as a result of the RREP. In addition to providing insights into the four key domains, the baseline explores two key areas: the first, current access to, and affordability of, energy among our target population. The second is qualitative insights into income generating activities that are currently taking place in communities. Both of these areas will serve to provide further insights for policy makers. (See Annex F: Knowledge Management Plan for further details.)

1.7 Baseline report structure

The findings section is structured around the key RREP research questions relating to the impact of the project.

Table 3: Key Baseline Research Questions and Structure of the Report

Key Baseline Research Questions	Report Section Addressing Questions
1. Does increased access to electricity increase incomes and assets?	Section 3.1
Agricultural production	
Non-agricultural activities	
Livestock and land ownership	
Household assets ownership	
2. Does increased access to electricity improve the health conditions?	Section 3.2
Acute Respiratory Infections (ARI)	
Eyesight	
Other disabilities	
Other disease prevalence	
Neo-natal and under-five mortality	
Maternal death	
3. Does increased access to electricity increase school attendance?	Section 3.3
Higher student attendance	
Improved literacy	
4. Does increased access to electricity reduce CO_2e emission?	Section 3.4
Reduced household fossil fuel consumption	

1.8 Data Ownership

UNOPS is the sole owner of all intellectual property, products, processes and documents that are developed for the baseline report and the Impact Evaluation. UNOPS has a perpetual license to use this intellectual property as it sees fit.[11]

[11] https://content.unops.org/service-Line-Documents/Procurement/UNOPS-General-Conditions-Services-2017_EN.PDF

Section 2: Methodology

This section provides an overview of the methodology and data sources developed and used by the impact evaluation team lead by WUR during the baseline assessment. Section 2.1 explains the approach to delivering the field work. Section 2.2 provides an overview of data cleaning processes. Section 2.3 explains the different streams of evidence employed to feed into the analysis. Section 2.4 explains the approach to measuring the impact of the thematic impact domains. Section 2.5 briefly covers the analytical approach used to report on baseline findings.

2.1 Approach to Delivering Fieldwork

The table below provides an overview of the approach to delivering the fieldwork.

Table 4: Approach to Delivering Fieldwork

Methodological Issue	Delivery approach	Reference for Annex
Research permission	WUR gained ethical and scientific approval for the entire impact evaluation research from the Office of the Sierra Leone Ethics and Scientific Review Committee (SLESRC). The approval is valid between 14 May, 2019 – 13 May, 2020.	Annex D
Sampling Approach	To evaluate the impacts of the mini-grids installed under RREP, the impact evaluation team employed a Difference-in-Difference design, comparing changes in key indicators in communities where mini-grids where installed with communities where no mini-grids were installed. To see the logic of our identification strategy, consider that the ideal means to identify the welfare effects of the RREP would be to compare two types of villages that on average have the same characteristics before the intervention, i.e. during the baseline survey, except that one was randomly allocated to receive the RREP intervention and one was not. We would then measure key indicators in both types of villages during follow up surveys. If welfare indicators were different in the two villages, we would be able to credibly claim that this difference was due to the effect of the RREP intervention. However, villages that received the RREP programme are, by definition, not the same as those that did not receive the intervention. The location of the mini-grid sites has been selected by UNOPS in consultation with other key stakeholders – e.g. the GoSL Ministry of Energy (MoE) – and may not be representative of the typical community in Sierra Leone. Specifically, each of the WP1/1+ community has a Community Health Centres (CHC) and a school. The WP2 villages tend to be larger in size. Therefore, during the selection process the team paid careful attention to the way that "comparison villages" were selected. These villages are those that we compare to the set of villages that received the RREP intervention. By carefully selecting comparison villages, *and*	Annex B

	assessing changes over time, we can create a credible counterfactual and minimize bias in our comparisons. To make causal claims about the impact of the RREP, we rely on a difference-in-difference comparison, which accounts for all time invariant differences between intervention and control villages. Causal identification in difference-in-difference relies on a parallel trends assumption— the assumption that outcomes of interest in treatment units are changing at the same rate as outcomes of interest in control units. The parallel trends assumption is credible to the extent that treatment and control units are similar along factors that drive changes in the outcomes of interest. In our case, this means that we should sample households from villages with similar characteristics. As a result, we use a matching algorithm to select villages that are similar to RREP villages. (See Annex B for more details.) Solar mini-grids were built prior to the baseline survey in treatment communities (WP1). These mini-grids electrified health clinics prior to the baseline survey. This means that our estimates for the effect of electrification on health outcomes will exhibit a downward bias. That is, we will *underestimate* the impact of electricity on health outcomes because part of the potential impact may have occurred *before* baseline and therefore will not be captured. To mitigate these concerns, our research team is collecting health clinic administrative data recorded *prior* to the implementation of RREP, data collection for which our research team has received permission from the Ministry of Health. In contrast, households in treatment communities *did not* have access to mini-grid electricity prior to baseline survey. This means that our estimates of the effect of electrification on household-level outcomes will *not* include downward bias. A possible exception is household outcomes that are affected by *expectations* of future electricity, rather than the flow of electricity. For example, if households expect to gain access to mini-grid electricity in the future, they may be more likely to purchase assets that use electricity. Again, these potential biases are only a concern for certain intermediate outcomes, but not for final outcomes such as changes in income. Moreover, we consider it unlikely that households will make substantial investments under the uncertainty of possible future access to electricity, before they have established connection.	
Respondent Attrition	As in every survey, risk of attrition is present. Our team will work to reduce attrition in the sample to the minimum. In order to do	N/A

	that, we will collect phone numbers, house/structure features, GPS location and address of all households interviewed. Once we come back in the future, we will be able to find the same respondents following this information. Expected attrition will be due to household members deaths or moving out of the community where they were living at the beginning of the project.	
Enumerator Training	WUR recruited 40 enumerators (30% female) for the primary data collection. All enumerators were trained on: - Basic enumerating skills - Interacting with human subjects - Ethical responsibilities - Purpose of the impact evaluation - Handling tablets and ODK Collect - Best practices for field research A considerable part of the training time was spent on each of the survey questions, analysing their purpose, meaning, expectations, reading and translations to Krio and other local languages. Enumerators were provided with Training Manuals, Scripts, Deployment Guides, and any other materials needed for the proper performance of their assigned tasks. One training took place for each data collection process.	Annex C
Pilot Testing	Three (3) pilot communities were selected within close proximity to Freetown in order to facilitate the logistics. These pilot communities were Malekuray, Kamasondo and Petifu. These communities were visited once before the start of the data collection period to test the validity of the instruments; and check for any mistakes due to the coding of the instrument; and the wording of the questions and/or the coherence of the complete questionnaire together. Pilot visits helped the team understand more about the culture and environment of the communities and to anticipate some of the challenges that could arise during fieldwork (language, logistics, roads, etc.). In addition to these three communities, the team used another two communities as “field tests” to test and evaluate enumerators’ understanding of the activity and its protocols. Since the impact and activities in these two communities was bigger, we decided to use two communities that were not part of the RREP.	N/A
Fieldwork Supervision	The Field Manager supervised all logistics and operational requirements prior to and during data collection. The field manager was in the field full-time during data collection periods, with additional time built in for preparation and closeout of field operations. Responsibilities included coordinating training and meeting venues, transportation and fuelling, distribution of per diems, addressing human resource requirements, and tracking field expenditures.	N/A

	The Field Coordinators supervised the teams of Enumerators, and were responsible for coordinating with the Research Associates to ensure timely data upload to the Data Manager, and quality control of collected data. They will also be liaised with the Field Manager for personnel and logistics requirements. Four Field Coordinators supervised a team of ten Enumerators. They were based full-time in the field during data collection periods.	
Enumerator Incentives and Retention	The Impact Evaluation Team lead by WUR instituted a system of awards, both monetary and nonmonetary in the form of certificates, given to enumerators with consistently high performance at the end of the field work. The performance was measured in three criteria: First, based on the quality of the data; second, the number of census surveys that the enumerator averaged throughout the duration of the field work; third, WUR asked the field supervisors, who had experience supervising each team at some point in the field work, to give recommendations on who they thought were the best enumerators in terms of their professional decorum, and level of enthusiasm.	N/A
Quality Control	Quality control was managed from Freetown by a team of Research Associates. Checks were made every second day and several course corrections were made. These took place either in the field or during feedback meetings each week in Freetown. Data was uploaded after each string/phase (every three days) and there was no missing or lost data.	N/A

In addition to the quantitative tools, the evaluation team used secondary data sources and qualitative methods to gain further insight into some of the key domain areas.

Secondary Sources

The evaluation team utilized several secondary data sources both in an effort to construct a representative control group for the mini-grid site, and to help the field team conduct their field work. The variables used in the matching algorithm were from census data that was provided by Statistics Sierra Leone. The datasets included a population level dataset containing demographic variables, population size, as well as the number and types of structures for every community in Sierra Leone. The census also included household-level asset variables that were used for wealth indices in the matching algorithm.

Statistics Sierra Leone also provided GPS coordinates of each community which significantly aided the field team to travel to their communities. The Ministry of Health and Sanitation provided a list of health facilities which was used to identify whether potential control communities had a health facility within the community - a necessary criteria for the inclusion into our sample frame. This facility-level dataset contained the names of the facilities, type of facilities, and their locations. Finally, the team also used Education Management Information System (EMIS) school census to determine how many schools were located in each community, and the names of those schools to help the field teams with locating them for the school survey.

Key Informant Interviews (KII)

Data was collected through interviews with key actors from Education, Energy, Environment Control and Health Authorities. KII were undertaken because these respondents had large experience and first-hand information on the related topics. Among them were some of the primary stakeholders of the programme, so their insights and opinion are very much needed to adequately evaluate the impact of the intervention.

Focus Group Discussions (FGD)

FGDs were conducted in communities. The goal of the FGDs was to collect more in-depth information from a reduced number of individuals that is otherwise not collected through quantitative methods. During FGDs, a facilitator helped the flow of the discussion, and monitored and guided the participants through the topics and questions covered. Due to the social dynamics of the FGD, participants usually feel more encouraged to reveal essential information.

2.2 Data quality and cleaning

The team developed rigorous processes to ensure that the data was of a high quality and that it was cleaned effectively. This included data storage, version control, peer review and communication processes to ensure that the data cleaning process was accurate, and the data is of the highest quality. The following are the steps taken by the data analysts to clean and manage the data for RREP.

For information on data protection please see Section 2.5: Inclusion and Ethics.

Table 5: Data Governance Processes

Data Governance Process	Description
Data Storage	Great care was placed in making sure that the data is properly organized into specialized repositories. Raw data, coding files, clean data, and any other outputs were each placed in separate file repositories. All raw data was stored in a "raw data" repository, organized into subfolders for the different surveys (household, school, CHC, etc.); all cleaning code files were stored in a "build" repository; and all clean data was stored in a "clean" repository. This ensured that work flows were efficiently systematized. For example, cleaning code in the "build" repository imported the raw data from the "raw" repository, processed it, and saved it into the "clean data" repository. This way, the data was be cleaned without overwriting the pre-existing raw data.
Version Control	Each file was allocated a version number indicated at the top of each cleaning file. When changes were made, the changes were recorded and noted down by the analyst as comments in the file, along with the name of the team member and the date. The version number enabled the team members track the changes that other team members have made. In addition, the cleaned files were periodically be moved into an "archive" folder, and a copy was made. The copy was then made part of the "active" cleaning file. Each copy was given a date in the name of the file so the team can quickly and accurately reference them. Having a historical record of

	changes also ensured that past data cleaning could be replicated in the case of a mistake in the code. In such a case, once the data analyst team spotted it, he or she could check which version the change was made, and at which date, then go to that version and reconstruct the previous dataset.
Peer Review	All data analysts communicated all changes that are made, and each analyst reviewed those changes after each version. In addition, every cleaning code produced a log file which results a full report that is printed at the end of the code. Log files were saved in their own repository and ensures that data analysts can review the changes even when the statistical software we use was not accessible. Log files display all commands, inputs, and outputs from the code for the data analysts to review.
Communications	The data analysts communicated over *Slack*, an online work platform through which team members sent messages to one another and shared snippets of code for each person to review and provide feedback. Using *Slack* as a platform for communication led to more efficient workflows. The analysts separated their operations into different "workspaces" for specialized tasks. In addition, all work was easily be communicated to the PIs for feedback, troubleshooting and high-level decisions.

2.3 Approach to Measuring Baseline

This section describes how the key thematic impact domain indicators are measured. The Key Indicators are grouped into four domains (as per ToR): 1) income and assets, 2) health, 3) education, 4) CO_2 emissions.

2.3.1 Measuring Thematic Impact Domains

This baseline assesses the current RREP outcome indicators across the four domain outcomes prior to the RREP interventions: 1) income and assets, 2) health, 3) education, 4) CO_2e emissions. The indicators and survey measure were selected based on two principles. Key Indicators a) comprehensively capture impacts of electrification on household income and assets and b) enable interpretation of *how* electrification leads to these changes. These indicators were obtained using three surveys, targeting different actors within a given community.

All data is disaggregated by age, gender and disability. For disability related questions the assessment used the Washington Group Disability Questions. With this information we will be in a better position to explain the mechanisms through which electricity is affecting households at the midterm and endline stages; and to understand the equity considerations of the electrification of rural communities.

Table 6: Key Indicators and Resource Streams

Domain	Key indicators	Description	Resource Stream
Household Income and Assets	Agricultural production	Quantity of agricultural products obtained during the last harvest (e.g. rice, cocoa, coffee, cassava)	HH Survey, KIIs, FGDs
	Non-agricultural activities	Wages earned from other activities like small businesses, service provision (bike	HH Survey, KIIs, FGDs

		rider), employment (teacher, civil servant)	
	Livestock ownership	Number/ type of livestock owned	HH Survey
	Land ownership	Size of land	HH Survey
	Household asset ownership	Value in SLL of all other assets in the household (e.g. fan, fridge, radio, cooking utensils)	HH Survey, KIIs, FGDs
Improved Health	Acute Respiratory Infections (ARI)	Presence of this condition in the past months	HH Survey, CHC records (if possible)
	Eyesight	Subjects self-report sight problems/difficulties in the past year (chronic)	HH Survey
	Other disabilities	Presence of any other	HH Survey
	Disease prevalence	Number of cases diagnosed	Registered Data
	Neo-natal mortality	Cases per thousands of children OR deaths during the first 28 days of life (0-27) recorded in the past month.	CHC Survey/ Registered Data
	Under-five mortality	Cases per thousands of children OR Under-five deaths in the past month	CHC Survey/ Registered Data (if possible)
	Maternal death	Cases per thousands of mothers during/after delivery – classified by "time of the day" based on availability on records.	CHC Survey / Registered Data (if possible) / HH survey
Education	Attendance	Number of days missed in the past month because student was working or helping out in household duties	HH Survey / school registers (if possible), KIIs, FGDs
	Improved Literacy	Administer a literacy test	HH Survey/Registered data (if possible)
CO_2 Reduction	Fuel consumption	Value in SLL of the consumption of diesel/petrol, batteries, kerosene, charcoal in the last 2 weeks	HH Survey, KIIs, FGDs
	Cooking facility	Type of kitchen/stoves used	HH Survey, FGDs

2.3.2 Description of Key Indicators

For each outcome domain, we first describe how the Key Indicators relate the high-level outcome domain indicators. Then we describe the specific survey measures that are used to construct these Key Indicators.

While describing how our key Indicators relate to outcome domain, we review *why* electrification might change Key Indicators - therefore reviewing the assumptions in the theory of change.

2.3.2.1 Domain 1: Household Income & Assets

Relation of Key Indicators to Outcome Domain

Electrification can impact income activities and assets accumulation in both agricultural and non-agricultural sectors. Only by measuring both can we obtain accurate assess *levels* and *changes* of impacts. If we fail to measure both agricultural and non-agricultural sectors, we may not accurately capture the impacts of electrification as changes in one domain may substitute or complement activities in another. For example, if electrification leads to an increase in small business employment, we would overestimate the impact if we failed to account for (potential) negative impact on agricultural production (as households leave farm for non-agricultural employment). Conversely, if electrification makes household activities more time efficient, excluding the agricultural sector would lead us to underestimate the impacts of electrification.

Electrification can directly stimulate agricultural income by enabling agricultural technologies such as water pumps, and indirectly by saving time on household activities that can be reallocated to agricultural work. In addition, extra income earned through electrification can be invested / stored in livestock. Electrification can increase non-agricultural income by stimulating local business, empowering value-added technologies, and increasing employment opportunities. Electrification can lead to the accumulation of household assets due to increased demand for these assets and higher levels of income leads to accumulation.

Key Indicator A: Agricultural Production

Our measure of agricultural production focuses on two key staple crops (rice and cassava) and two key cash crops (coffee and cocoa). We measure how much of each crop is grown, harvested, and sold. This allows us to untangle changes in both consumption patterns and product sold.

Key Indicator B: Non-Agricultural Activities

It is possible that electrification drives small business growth. Our survey captures whether the respondent or their spouse owns or is employed by a small business and how much time they commit to this activity. We also track the electricity usage of the small business and revenue, costs, and profits associated with the business, and wages associated with employment

Key Indicator C: Livestock Ownership

We catalogue all animals owned in the household -- ownership defined as the right to kill or sell the animal. We also quantify what share of the household's animals are (at least) jointly shared by women.

Key Indicator D: Land Ownership

Land is an important indicator of wealth and agricultural production potential. We capture the total size and value of land owned by the household.

Key Indicator E: Household Asset Ownership

We probe respondents on their ownership of 29 different household assets. Importantly, we measure baseline ownership of electrified assets, so that we may gauge how electrification affects the adoption of electrified assets over time.

2.3.2.2 Domain 2: Improved Health

Relation of Key Indicators to Outcome Domain

Electricity has the potential to drastically improve health outcomes. We measure health impacts though a) household surveys and b) CHC administrative records and CHC surveys. Electrification can improve health directly by a) changing household conditions, such as cooking conditions or b) improving hospital conditions, and indirectly by c) increasing household income or d) modifying health-seeking behaviour. Specifically, changes to household conditions can have impacts on respiratory and eye issues, two problems we measure directly. Improved (electrified) hospitals may stay open later and be better able to provide important pre- and post-natal care to women. When hospitals are better equipped, pregnant women may be more willing to deliver their babies at hospitals. Increased income from electrification may allow households to better deal with preventable diseases, such as malaria. We directly measure household health outcomes for children under five and for women who have recently given birth. In addition, we capture disability data for household members and will measure how electrification effects differ between households where some members have disabilities and households where members do not suffer from disabilities.

Key Indicator A: Acute Respiratory Infection (ARI)

To measure the prevalence of ARI, we first ask respondents if there are times when they experience the symptoms of ARI: difficulty breathing, runny nose, cough, and sore throat. We then ask if these symptoms have been experienced by the respondent in the last 30 days, and for how many days. In addition, we measure health seeking behaviour, asking respondents if they sought medical treatment and if so, which type of medical treatment.

Key Indicator B: Eyesight

To measure the impacts of electrification on eye conditions we first asked respondents if they suffered from problems with itchy, tired, red or burning eyes. Blurred and cloudy vision. We use a Krio word, common in other Sierra Leonean languages, that people usually use to describe this set of symptoms: *"apolo".*

Key Indicator C: Other Disabilities

We measure other disabilities for every person on the household roster through using the Washington Disability Group Questions. We used the Short Set[12] of questions, which are designed for use in questionnaires that are measuring a multitude of socio-economic indicators. They primarily focus on measuring whether people have difficulty universal basic functions and identifying a portion of population that is at risk of participation restrictions. While the Short set of questions do not go into extensive detail on disabilities, they enable disaggregation of other measures by disabilities (in our survey these are income, education, and CO2e emissions. Each household member is asked if they have difficulty seeing,

[12] http://www.washingtongroup-disability.com/washington-group-question-sets/short-set-of-disability-questions/

hearing, walking or climbing steps, remembering or concentrating, self-care (such as washing or dressing), or communicating in their primary language. We create a disability index based on responses to these questions.

Key Indicator D: Disease Prevalence

Many common diseases are preventable. It is possible that electrification leads to a decrease in preventable diseases, either by increased drug or service availability at health clinics, or changes in health seeking behaviour. In our household survey we measure the prevalence of malaria symptoms as a proxy for common and preventable diseases. In our health centre survey, we measure the stock of vaccines and drugs, and the presence of medical equipment that might lead community members to seek out services.

Key Indicator E: Neo-Natal Mortality

First, we ask if there is a woman in the household who has given birth in the last year. If the answer is affirmed, we ask about the pre-natal care that the woman received and where she sought it. We then ask if any pregnancy ended in stillbirth in the last 12 months.

Key Indicator F: Maternal Death

We ask if there has been a woman in the household who died during childbirth in the last 12 months. Asking about death can be a sensitive topic. Our survey protocol instructs enumerators to start with facts before moving to the question. Enumerators state: "During delivery, women sometimes suffer complications and bear the risk of dying." Only then do we ask if there has been a woman who died during childbirth in the last 12 months.

2.3.2.3 Domain 3: Education

Relation of Key Indicators to Outcome Domain

Below we describe how we measure our two primary education outcomes: attendance and literacy. However, our surveys also contain data that helps us to interpret *how* electrification might improve these educational indicators. Specifically, we capture how school children allocate their time between: farm work, house chores, recreation, studying, and sleeping. We also measure how children's educational experience might change through electrification, focusing on: teacher attendance, hours of operation, energy access and electrified appliances.

Key Indicator A: Attendance

First, we record the household members who are currently in school and capture the educational achievement of those who are no longer in school. Then we ask how many days of school each child has missed in the last week (excluding holiday). We average this across the household for a household level attendance indicator.

Key Indicator B: Improved Literacy

While we have village-level measures of literacy at baseline (taken from 2015 census), we do not have a baseline household measure of literacy. We plan to capture this measure at endline by administering a test in all schools, and accessing existing test result data.

2.3.2.4 Domain 4: CO_2e Emissions

Relation of Key Indicators to Outcome Domain

Rural households create emissions mainly though the energy used for household lighting and cooking. We measure these two indicators with a comprehensive set of survey questions.

Key Indicator A: Fuel Consumption

We capture the use of fuel in cooking and lighting the house. Specifically, we measure the amount of money spent on kerosene, firewood, charcoal, and petrol for lighting and cooking. We then use the market price to back out the quantity of each, and convert to CO2 emissions. Electricity should reduce reliance on these "dirty" fuels.

Key Indicator B: Cooking Facility

Home cooking is a leading are of CO_2 emissions in rural households. Electrification allows for the adoption of "clean" electric cooking facilities, such as electric stoves. We measure if households adopt clean cooking technologies.

2.3.2.5 Monetizing Impacts

The impact of the RREP will be measured in terms of cumulative increase in welfare, measured in financial improvements. We aim to monetize key changes in the main four outcome groups. This conversion will be used to assess progress against Impact Indicator 1 (i.e. achieving a 100m GBP welfare increase) as a result of the project. These welfare improvements are presented from the standing of rural households, projected over the life time of the project (50 years) and appropriately discounted.

Below we summarize the core conceptual approach to the conversion into monetary equivalents of changes in the four domains of interest.

Household Income and Assets

Indicators from "Section 2: Income and Wealth" can be used to measure how much income and assets have changed for programme beneficiaries. Such a measure is expressed in monetary terms already, and the team will calculate the present value of the change due to the mini-grids by choosing appropriate time horizon of the programme and discount rate.

Improved Health

Indicators from household survey "Section 4: Health Related Data" and CHC survey can be used to calculate the monetary value of RREP induced health improvements. We quantify the monetary impacts of a) reductions in child mortality, b) reduction in maternal mortality, and c) reductions in disease burden. Our strategy for monetarizing the impacts of these three categories is as follows:

A. Child Mortality

To monetize potential reductions in child mortality, we take our Difference-in-Difference estimate of the reduction of child mortality due to RREP and multiply by current scholarly estimates of the effect of child mortality on GDP, taken from top public health journals. One recent study in a top public health journal estimates GDP losses per child death at $25,508.[13] We incorporate uncertainty by considering 95% confidence intervals of both RREP child mortality reduction estimate and the literature's estimate of impact of child mortality on GDP.

B. Maternal Mortality

To monetize potential impacts of maternal mortality, we rely on a similar strategy as the one outlined above for child mortality. We take our Difference-in-Difference estimate of the reduction of maternal mortality due to RREP and multiply by current scholarly estimates of the effect of maternal mortality on GDP, taken from public health journals. One recent study finds that a one percent reduction in maternal mortality leads to a 0.11 percent increase in GDP.[14] We can leverage this study to estimate the impact of the RREP programme, by calculating maternal mortality in RREP communities as a percent of national maternal mortality. For example, if RREP sites at baseline contain 1% of all maternal mortality in Sierra Leone and – following the study cited above— a 1% reduction in maternal mortality in RREP sites leads to an estimated .0011 increase in national GDP, then the 1% reduction in maternal mortality through RREP will lead to a .0011 percent increase in GDP. Taking the current GDP in Sierra Leone at 4 billion, that's an impact of 4.4 million USD to GDP.[15] Again, we incorporate uncertainty by considering 95% confidence intervals of both RREP child maternal reduction estimate and the literature's estimate of impact of maternal mortality on GDP.

C. Disease Burden

To monetize potential impacts of disease burden, we follow the conceptual framework outlined by the WHO's "Guide to Identifying the Economic Consequences of Disease and Injury".16 The authors of this guide note, "in the simplest case, the incidence of disease or injury event has two immediate potential effects. Firstly, the diseased or injured person may have to reduce their normal level of productive activity, secondly, the household may have to increase its consumption of health services or goods" (pg. 62). Within this framework, we leverage our survey data which contains information on health expenditures and information on the frequency by which respondents have suffered from common illness in the past 30 days. Under certain assumptions, we can compute economic loss from these events.

First, to estimate impact on productive activity, we take our Difference-in-Difference estimate of reduction in sick days due to RREP and multiply it by average daily income (calculated from income section of survey). This estimate depends on assumptions about the degree to which sickness leads to productivity loss. That is, people may still work when sick. Therefore, we calculate different estimates under different assumed levels of productivity loss.

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[13] Kirigia, Joses M., et al. "Counting the cost of child mortality in the World Health Organization African region." *BMC public health* 15.1 (2015): 1103.

[14] Kirigia, Joses M., et al. "Effects of maternal mortality on gross domestic product (GDP) in the WHO African region." *African journal of health sciences* 13.1 (2006): 86-95. This article has been cited in leading health and medical science journals, for example *The Lancet* (Langer et al. 2015).

[15] https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=SL&view=chart

[16] https://www.who.int/choice/publications/d_economic_impact_guide.pdf

Second, we estimate reductions in health treatment / service costs associated with health benefits of RREP. A crucial assumption here is that the RREP does not affect demand for health services. If we drop this assumption., we can still estimate reductions in health treatment / service costs associated with health benefits of RREP, by controlling for differences in demand for health services at similar health levels.

Education

Similar to our strategy for monetizing the impacts of "Improved Health", the team will use household survey "Section 5: Education" and school survey to measure possible improvements related to schooling, such as school attendance, educational attainments and literacy rates.

There exist many ways of estimating value for money in poverty reduction interventions. In virtue of its simplicity and international acceptance, we will use this framework to support our monetarization of education outcomes. Our preferred method for calculating the value for money, common in the field of education, is to assign monetary value to additional schooling years enabled by the implementation of a programme. It is well known in the education literature that additional years of education are associated with higher lifetime earnings (Card, 1999)[17]. To calculate these lifetime earnings as a function of years of schooling, it is common to use a Mincer's human capital earning function. This Mincer equation explains earnings as a function of schooling and labour market experiences, estimating the average monetary returns of one extra year of schooling.

Due to the lack of large longitudinal dataset that reliably estimates the returns to education in Sierra Leone, we need to make use of existing literature in Sub-Saharan Africa, West Africa or a country in the same geographical area and similar background characteristics as Sierra Leone. Literature on Sub-Saharan Africa and on Ghana are available, that can be used for the purposes of this analysis. See Annex I for more details, including the specific assumptions made and an example of the method.

CO_2e Reduction

Survey questions contained in "Section 3: Energy Use" can be used to estimate possible reduction in CO_2e emissions associated with reduced use of generators, combustion of other fossil fuels and batteries for lightening (and/or cooking). Reduced CO_2e emissions can be valued using international standards and associated impacts on the environment for the duration of the programme and discounted to calculate present value.

It is important to point out that conversion of these indicators into monetary equivalent often requires strong assumptions which are not free of critique. The evaluation team will be working together with UNOPS M&E to choose the most appropriate assumptions for the valuation of benefits.

[17] Card, D. (1999). The Causal Effect of Education on Earnings. *Handbook of Labor Economics*

2.4 Approach to Reporting Baseline Findings

2.4.1 Approach to Survey Response Bias

In this section we detail our strategy for dealing with common forms of survey response bias. Given the ethnic and linguistic diversity of Sierra Leone, we might be concerned about various forms of interviewer bias-- be it the place of birth, ethnicity, or first language of the interviewer.

Interview language bias & bias vs. measurement error

Krio was the default language for conducting all surveys. However, because enumerators were sent to areas where they had linguistic speciality, enumerator and respondent sometimes matched on a non-Krio primary language, and then the interview was conducted in that language. This means respondents who speak major languages (i.e. Mende / Temne) as a first language are more likely to have the interview conducted in their primary language than respondents from minor languages. If enumerator and respondent did not share a primary language, and the respondent did not speak Krio, a trusted person was recruited to translate. Both of these situations - speaking in a mother language or speaking through a translator - deviate from the default option of Krio and may engender different responses.

We do not expect there to be large "language effects" as language would most likely affect responses through for sensitive questions where trust / familiarity is important; our survey data does not hinge on sensitive questions. Moreover, it is important to distinguish between "measurement error" and "bias". Measurement error occurs when the level of an outcome captured in a survey differs from the true value of the outcome; every question on every survey contains some degree of measurement error. However, "bias" comes into the picture when respondents in treatment and control respond to questions in a different way. There is no reason to expect that we will have more measurement error in treatment compared to control communities. This means we have no reason to expect language bias errors.

The same logic can be applied to other factors that may create measurement error, such as a) respondent and interviewer of different gender, b) respondent and interviewer from different region, c) respondent and interviewer from different class backgrounds. While all of these might introduce a certain degree of measurement error, we can expect this measurement error to be equal in treatment and control and therefore create no bias.

2.4.2 Relevance of the Sampling Regime

We use probability sampling to obtain a group of respondents that are representative of the whole town. A main tenet of probability sampling is that every unit has the same probability of being selected into the survey. This would not be achieved through a simple random sample that utilized a "random walk" procedure. In a random walk strategy, respondents selected are a product of where one enters the town or from where one begins their "random walk" which is usually the centre of town or someone other important building; this cannot be considered a random part of town. To avoid this problem, we use a town census to develop a full list of households. We then randomly sample household from this list. (See Annex B for more information on our sampling strategy).

Our use of probability sampling means that we can assume that our household survey is representative of the village population. One issue that could potentially challenge the representativeness of our survey is non-response. Non-response can create bias if non-response patterns are different across treatment and control. We can test for this pattern by regression treatment status on non-response in a given variable. If there are differences across treatment and control, we can analyse *which* kinds of people are not responding so that we can better interpret out findings.

2.5 Inclusion and Ethics

A detailed inclusion and ethics approach was applied to the baseline assessment, taking into account DfID's commitment to human rights-based approaches of participation and inclusion, non-discrimination and equality, and accountability. WUR has been working in Sierra Leone for 15 years, and has conducted a large number of research projects. In this time it has adhered to international standards of ethical conduct, and developed an in depth understanding of power dynamics, inclusion, and equity issues during research processes.

Respondents were selected randomly from village listings to ensure the sample was representative and inclusive of marginalised households. Female headed households were interviewed for relevant questions The team did not interview children directly.

The Impact Evaluation team received ethics approval from the WUR Social Sciences Ethics Committee (SEC). The SEC stated that the proposal dealt with ethics issues in a satisfactory way, and that it complied with the Netherlands Code of Conduct for Research Integrity. The team also received ethics approval from the Government of Sierra Leone Ethics and Scientific Review Committee (SLESRC).

2.5.1 Data Protection

A number of precautions were taken to ensure the confidentiality of all information collected from subjects in the studies it conducts. Administrative data was collected using Open Data Kit (ODK) software on smartphones/tablet and was sent to the server through 3G. Other than usage analytics and crash reports ODK software does not send or communicate any survey data information back to ODK servers. When we do gather data, we default to anonymous or aggregate methods. An encrypted version of the database is stored on Dropbox and made accessible only to those in possession of a password that is shared exclusively among members of the research team. All data is backed up on an external hard drive that will be kept in the research team's office, where only authorized persons are permitted.

No identifiable data is ever published or passed to any third party, since the digitized data collected are automatically encrypted. This means that not even the person collecting the information had access to it. No identifiable data is ever printed. WUR field staff have access to some identifiable data (names, dates of birth, and village names). This data is exclusively used to identify respondents for follow up surveys and to verify the accuracy of administrative data. This data will be stored securely on mobile devices under password protection. Other researchers assisted the Principal Investigator's (PI) team for data analysis and report writing. These researchers were granted access to de-identified data only (withholding names of respondents).

2.5.2 Informed Consent

All individuals were informed of the identity of the survey enumerator, the nature of the survey, informed of their right not to participate in the survey, and of their right to refuse to answer any question during the survey. Moreover, individuals were informed of the confidentiality of the data, and given information about who to contact in case they have any questions about the status or use of the survey. Only after all of the above was described to the individual was the individual invited to participate in the survey. Enumerators orally translated the informed consent into local languages (English, Krio, Mende, Temne, depending on the site) when they administered surveys.

2.5.3 Withdrawal From Study

All study participants have the right to withdraw from the study at any point. The study focuses on the impact of electrification, complementary inputs, and market access on development. Withdrawing from the study means that potential beneficiaries do not disclose information to the research team. If any community member decided to not disclose information, she/he was free to do so. Withdrawal from the study in no way affects the subject's relationship with the study team or any partner associated with the study team.

2.5.4 Risks and Benefits to Participation

It was ensured that there were minimal risks to respondents from participating in both the intervention and the questionnaire. WUR informed participants that this study will benefit subjects by helping to identify how benefits of electrification can be maximized for the beneficiaries. One risk that the team considered was the possibility of animosity as a result of being a comparison village and not gaining access to electricity through the mini-grid. Enumerators explained to participants that better quality data will enable the government to make informed decisions about how to best electrify communities, identify which sub-populations to target first, and what complementary technologies to improve access to.

The questionnaire content is of a non-sensitive nature, and WUR designed the survey process to take as little time as possible from the respondent during interviews. The team also recruited field staff who as far as possible spoke the appropriate local language to ensure that the respondents feel comfortable.

Section 3: Descriptive Analysis and Results

3.1 Income and Assets

Electrification can impact income activities and asset accumulation in both agricultural and non-agricultural sectors. Electrification can directly stimulate agricultural income by enabling agricultural technologies; and indirectly by saving time on household activities that can be reallocated to agricultural work. In addition, extra income earned through electrification can be invested or stored in livestock. Electrification can increase non-agricultural income by stimulating local business, empowering value-added technologies, and increasing employment opportunities. Electrification can lead to the accumulation of household assets due to increased demand for these assets and higher levels of income leads to accumulation.

3.1.1 Agricultural Production

Our measure of agricultural production focuses on two key staple crops (rice and cassava) and two key cash crops (coffee and cocoa). Table 7 reports the proportion of household participating in each activity. As expected, staple crops (rice and cassava) are much more likely to be grown than cash crops. 54 percent of the households surveyed grow rice and 27 percent grow cassava, compared to only 8 percent of households who report they grow cocoa and 4 percent reporting they grow coffee.

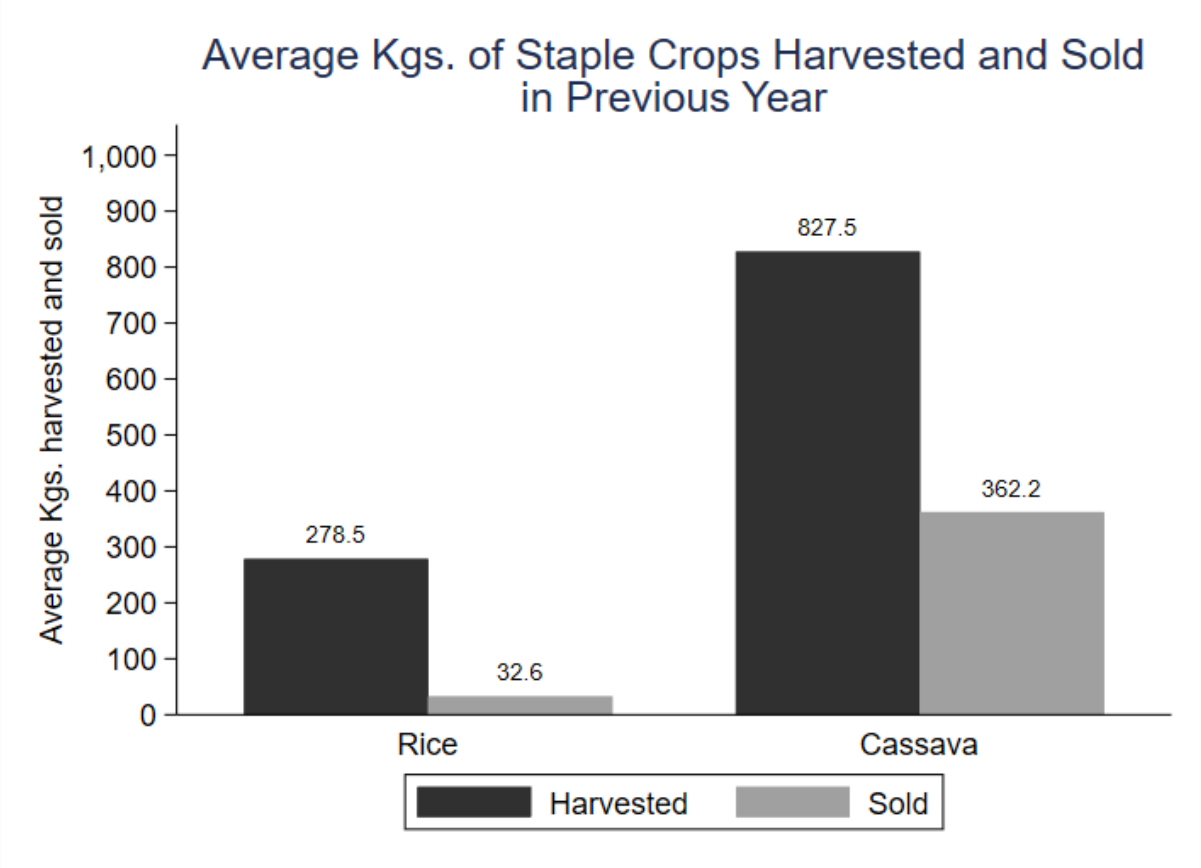

Figure 2: Staple Crops Harvested vs Sold

The figure above shows the average kilograms of staple crops that were harvested and sold by our sample in the previous year. While both staple crops are mainly for consumption, farmers are more likely to sell cassava than rice. Less than 10 percent of rice harvested is sold at market, while nearly half of cassava is sold at market. Table 7 provides a more detailed breakdown of production and selling patterns by crop.

Table 7: Agricultural Variables Summary Table

	No. of Observations	mean	sd	median	min	max
Grows Rice	3257	0.54	0.50	1.00	0.00	1.00
Kgs of Rice Harvested	1740	278.46	394.00	162.50	0.00	7500.00
Kgs of Rice Sold	1732	32.61	111.50	0.00	0.00	1500.00
Grows Cassava	3257	0.27	0.44	0.00	0.00	1.00
Kgs of Cassava Harvested	838	827.50	1102.97	372.00	0.00	6200.00
Kgs of Cassava Sold	826	362.25	682.16	0.00	0.00	4960.00
Grows Cocoa	3257	0.08	0.27	0.00	0.00	1.00
Kgs of Cocoa Harvested	177	79.21	130.13	15.00	1.00	840.00
Grows Coffee	3257	0.04	0.20	0.00	0.00	1.00
Kgs of Coffee Harvested	110	64.23	87.53	20.00	1.00	370.00

There is much more variation in production among farmers growing cash crops than farmers that grow staple crops. Of households that grow rice, the average harvested is 278.46kgs. The median harvest sits at 162.5kgs. Of farmers who grow cassava, the average harvested is 827.5kg and the median harvested is 372kg. The fact that the mean sits above the median can be interpreted as there being a greater number of small-scale farmers producing less than average compared to large scale farmers who are producing more than average— but the differences in production between the top 50 percent of farmers and the bottom 50 percent of farmers is not very large.

This is in stark contrast to cash crop production, where there is substantial variation in production amongst farmers that grow cash crops. 8 percent of our sample planted cocoa trees and among these cocoa growers 177 reported harvesting cocoa over the past year. 79.21kgs of cocoa were harvested. Out of the 4 percent of coffee growers in our sample, 110 reported harvesting coffee this past year. 64.23kgs of coffee were harvested. There were also a portion of cocoa and coffee growers who reported zero harvests this past year. This could be attributed to crops being recently planted. It is normal for coffee plants to take 2-3 years for the first harvest, with plants being productive for nearly 5 years after[18]. Similarly, cocoa plants flower after two years of planting[19] so there won't be harvests for a few years. The numbers presented above are for households that reported yields more than zero.

[18] http://producemonitoringboard.sl/harvest-and-post-harvest-2/

[19] http://www.fao.org/3/AD220E/AD220E05.htm

Figure 3 breaks down staple crop production patterns by disability status. Each of the six sub-figures displays harvesting and selling habits for both rice and cassava in each of the six disability domains. The bars on the left side of each figure represent harvesting and selling patterns for non-disabled people, while the bars on the right side of each figure represent harvesting and selling patterns for disabled people. On average harvesting and selling patterns seem to be fairly consistent between disabled and non-disabled households, across each disability category and we perceive no systematic differences at baseline.

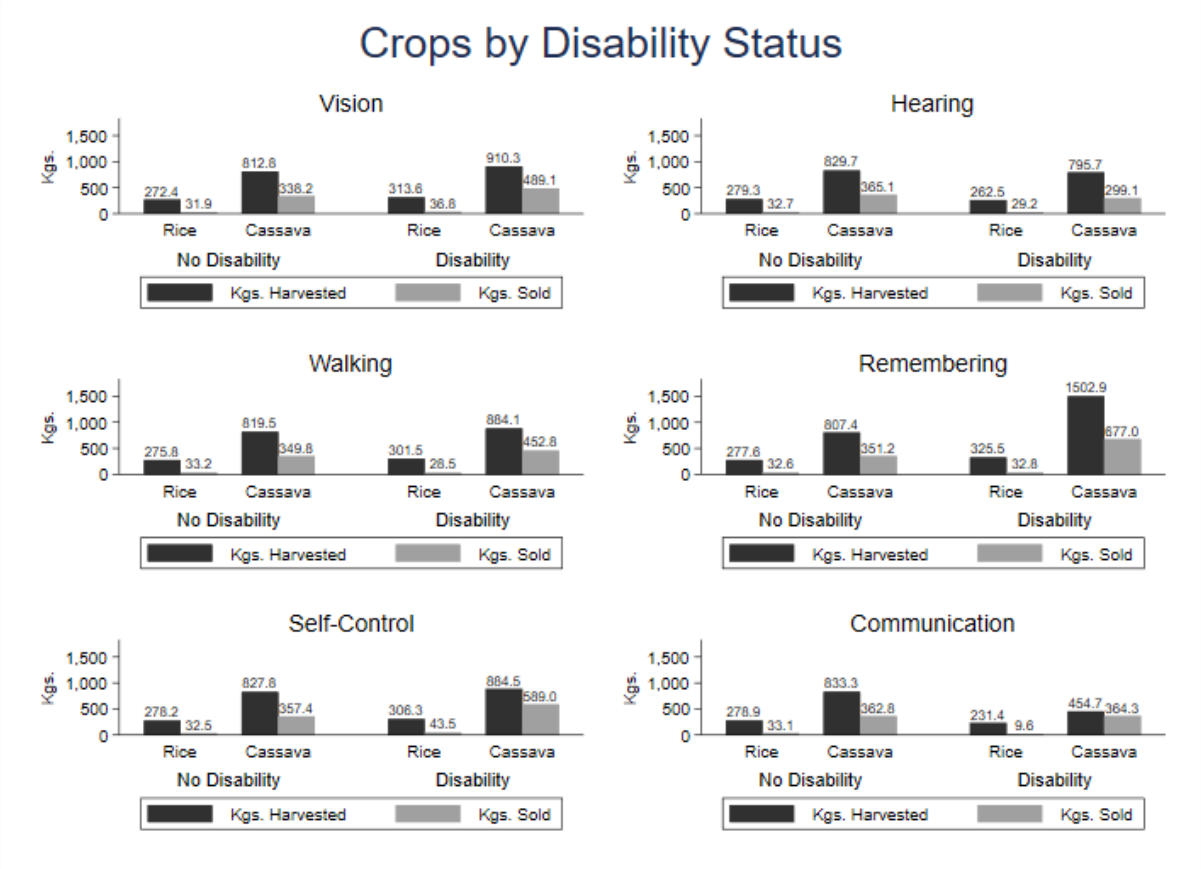

Figure 3: Crops by Disability Status

Table 8: Balance Table: Agricultural Variables for Mini-grid Sites and Non-Mini-grid Sites

Variables	Control	Treatment	Difference in Means
	(1)	(2)	(3)
Bushels of Rice Sown	1.853	1.555	0.298
	(0.184)	(0.158)	(0.241)
Kgs. of Rice Harvested	162.984	140.274	22.710
	(19.219)	(14.602)	(24.029)
Kgs. of Rice Sold	17.708	17.449	0.259
	(4.275)	(3.209)	(5.321)
Heaps of Cassava sown	116.519	57.784	58.734**
	(20.056)	(10.877)	(22.714)
Kgs of Cassava Harvested	242.095	174.855	67.240*
	(29.168)	(23.691)	(37.409)
Kgs of Cassava Sold	100.475	82.773	17.702
	(17.869)	(15.832)	(23.766)
Kgs of Cassava Sold	80.985	66.196	14.789

	(14.155)	(12.368)	(18.715)
Cocoa trees planted (2018)	34.462	18.722	15.740
	(11.462)	(6.047)	(12.902)
Kgs of Cocoa harvested (2018)?	4.385	4.326	0.059
	(1.785)	(1.516)	(2.331)
Coffee trees planted 2018?	25.531	17.536	7.995
	(10.173)	(10.466)	(14.529)
Kgs of Coffee harvested (2018)?	2.415	1.957	0.457
	(0.942)	(0.736)	(1.190)
N	1631	1709	3340

This table shows a balance test between treatment and control for the non-agricultural variables.
Standard errors are clustered at the village level. *p<.1 **p<.05 ***p<.01
Standard errors are reported in parentheses.

Table 8 compares how agricultural activities differ across treatment and control communities. For staple crops, control communities report a statistically significantly higher level of cassava sown, and harvest. There is no reported difference in rice production or selling patterns across treatment and control. While point estimates for cash crop investments in planting cocoa and coffee trees is higher in control communities, these differences do not reach a statistically significant level. Figure 4 illustrates the differences between treatment and control across harvested and sold rice and cassava.

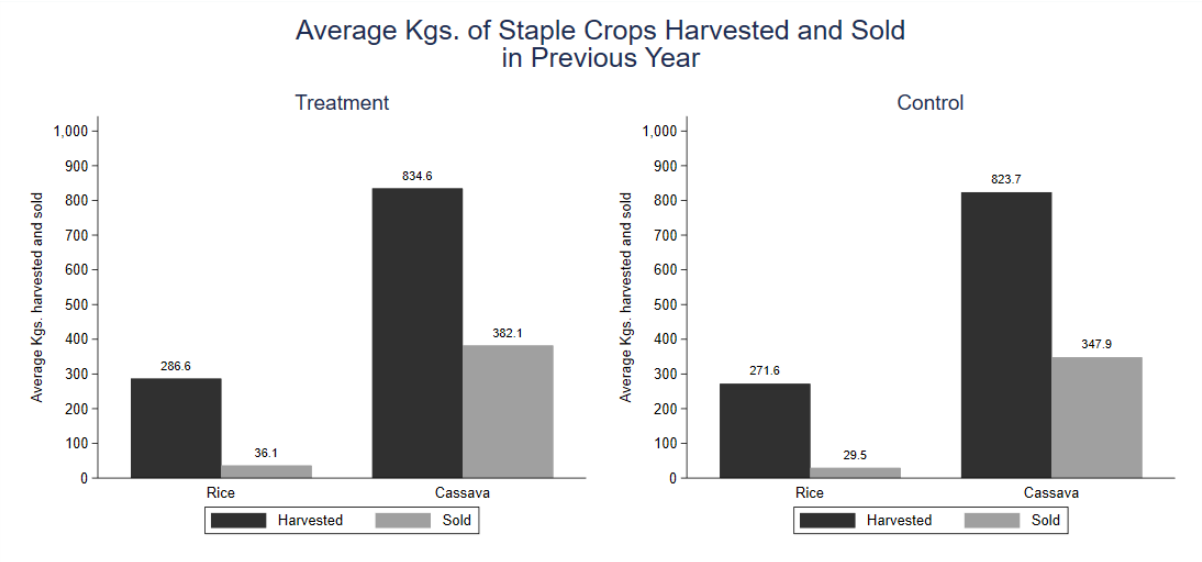

Figure 4: Cash Crop Production by Treatment Status

It is important to note that our difference in difference estimation strategy relies on a parallel trends assumption – outcomes in treatment and control are *changing* at a similar rate – and does not require that the *levels* of treatment and control are the same at baseline. If electricity improves agricultural production, we will still be able to observe a larger shift in production in treatment than in control. Finally, it should be noted that imbalance between treatment and control *does not indicate improper matching*. Rather, as a goal of the RREP was to generate high impact by working in populated areas, it is logical that communities that are available to serve as comparison will be different than communities that received the RREP.

3.1.2 Non-Agricultural Activities

Electricity can also be an engine of structural change, shifting rural economies from agrarian subsistence towards non-agricultural enterprises. We capture baseline measures of non-agricultural employment and existing uses of electricity, investigating how these outcomes differ across gender and disability status, and between treatment and control villages.

Individuals who are employed outside of the agricultural sector are more likely to work for themselves than working for an external employer. Table 9 — which reports that a substantial 31 percent of respondents and respondents' spouses are self-employed, whereas only 8 percent of respondents and respondents' spouses are formally employed at an organization where they receive a salary. As can be seen in Table 9, individuals who work for a formal organization have an average net salary of almost 860,000 SLL per month. In contrast, the self-employed do not report much business success.

Table 9: Non-agricultural Employment Outcomes

	n	Mean	Median	Min.	Max.
Self-Employed and owns a business	5067	0.31	0.00	0.00	1.00
Hours worked at own business in a typical week	1527	40.72	40.00	0.00	91.00
Own business requires electricity	1582	0.21	0.00	0.00	1.00
Monthly Revenue from own business	1130	570.68	250.00	0.00	6000.00
Monthly Cost from own business	1165	506.22	200.00	0.00	6000.00
Employed in a formal organization with salary	5063	0.08	0.00	0.00	1.00
Net salary from formal organization	256	862.79	700.00	0.00	12000.00

Our sample contained outliers that were driving the results. From our results it seems as if there are two types of small business owners in our sample. One with reasonable investment costs and revenues, the other with high investment costs that aren't reasonable for a small business. These businesses also earned profits that were very low compared to the costs. These might be businesses who earn their costs back over a longer period, such as traders who buy their goods in bulk and sell it over a few months. In our data, these businesses spent more than 2,000,000 SLL but earned less than a million per month. 65 such observations were dropped from our sample. The results presented do not include them.

Figure 5 shows the average monthly profits across all self-employed individual's is 302,300 SLL. The median profit per month is 100,000 SLL.

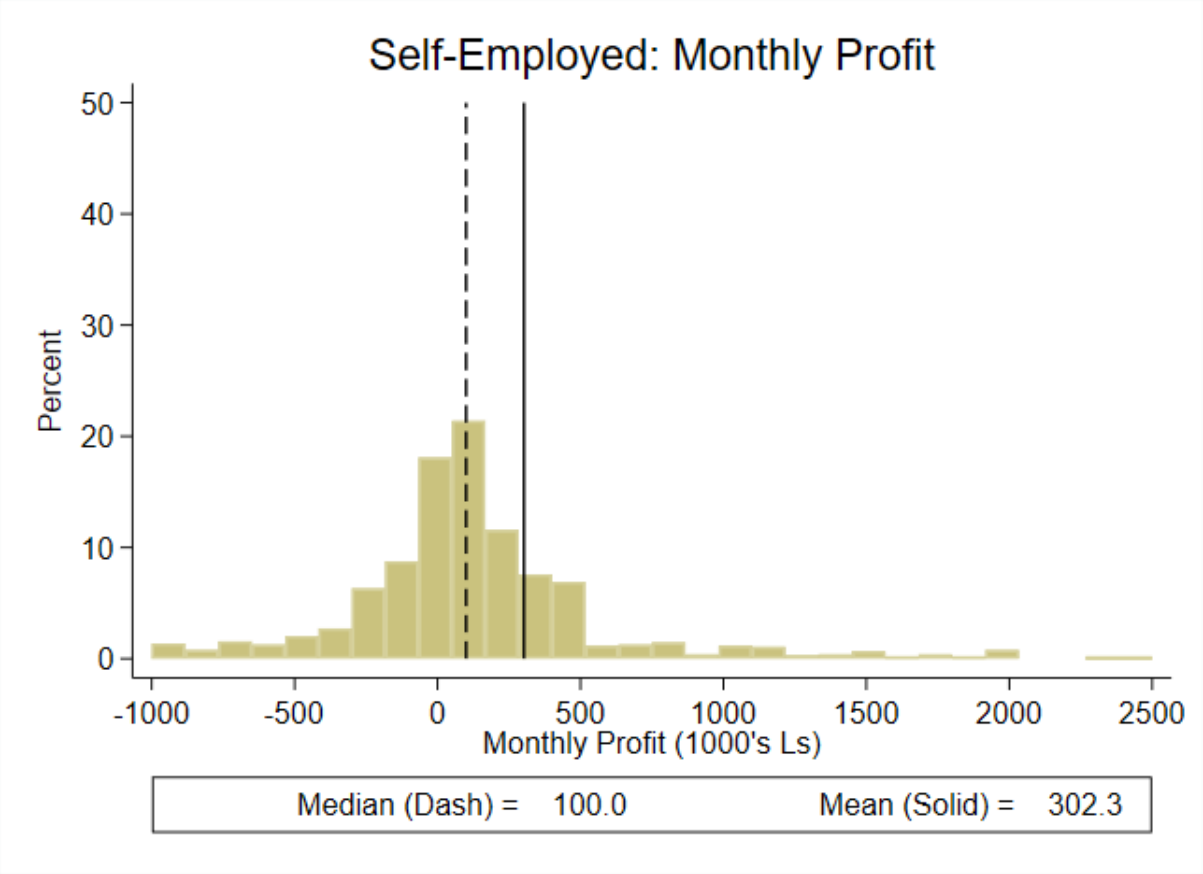

Figure 5 - Profits for Self-Employed individuals

This is a strikingly low average profit figure, as it is not from lack of hours invested in self-employment Figure 6 shows the distribution of the number of hours per week worked by the self-employed. Self-employed individuals work an average of 41 hours per week and 50 percent of self-employed individuals work more than 40 hours per week.

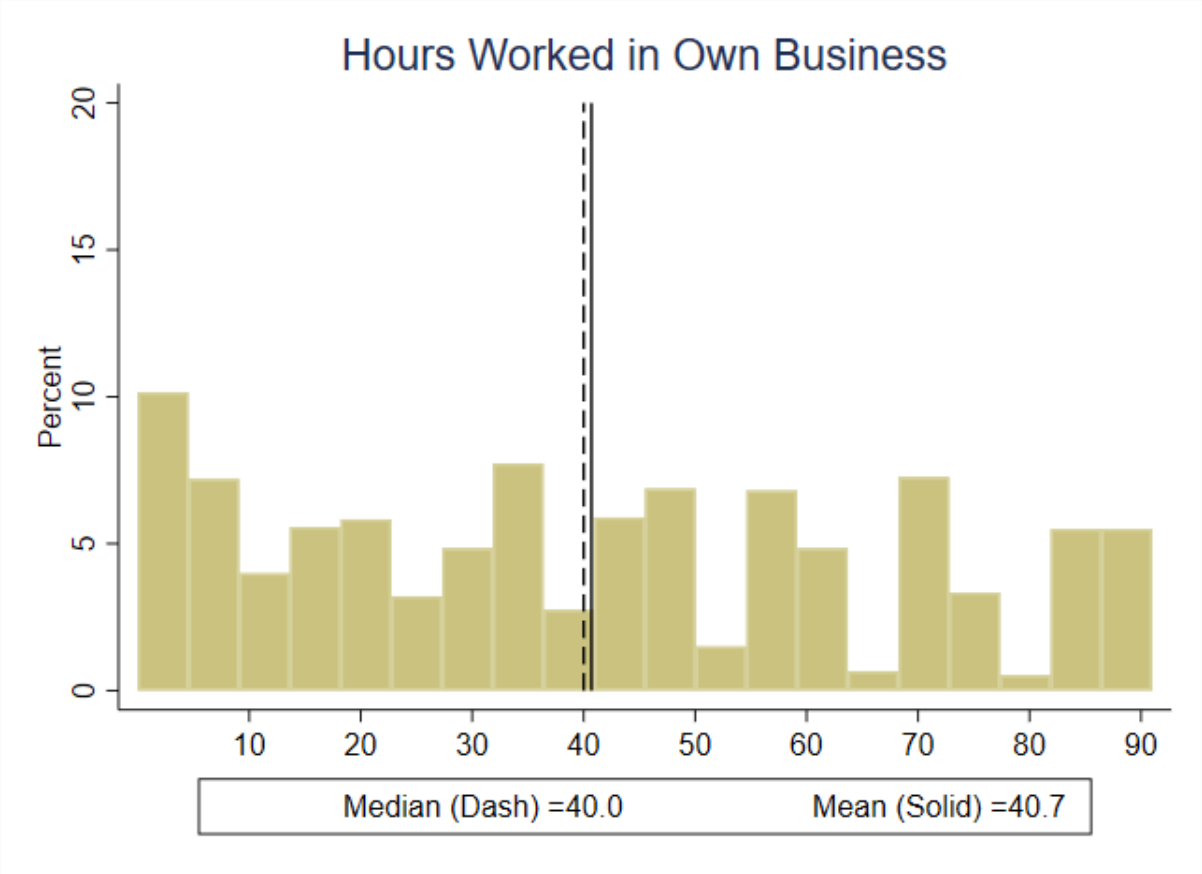

Figure 6: Hours worked per week by Self-employed individuals

Figure 7 and Figure 8 below add nuance to our understanding the performance of entrepreneurs at baseline. Figure 7 shows the percent of self-employed individuals that work in each business type, and Figure 8 breaks down average business profits by business type. 46 percent of all self-employed classify themselves as "petty traders", where generating profits seems particularly difficult. Petty traders report an average profit of 136,100 SLL per month. An additional 21 percent classify themselves as "farm traders", who presumably sell agricultural products at market. Farm traders fare a little better, generating an average profit of just of 515,000 SLL per month. The most lucrative self-owned business type is running a telecentre, with reported profits of 714,000 SLL.

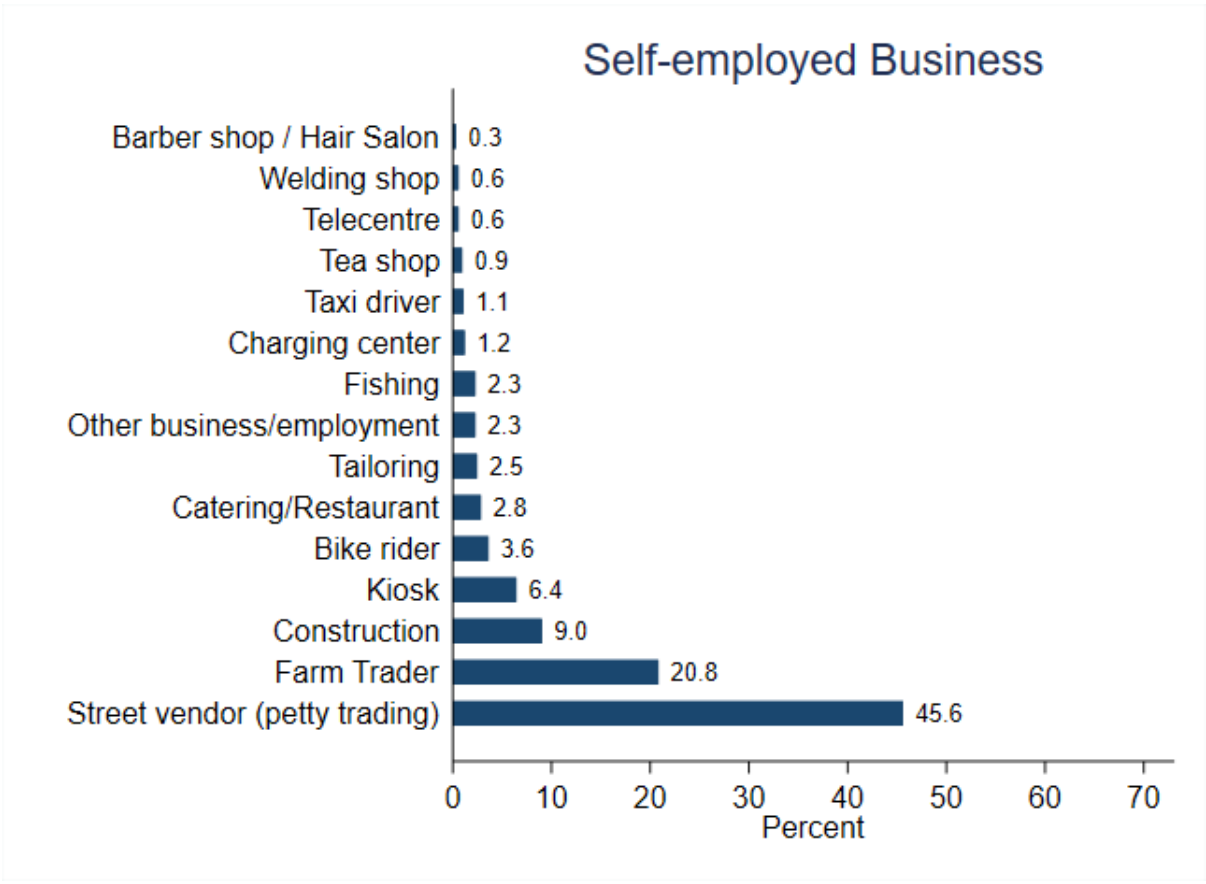

Figure 7: Self-employed business type

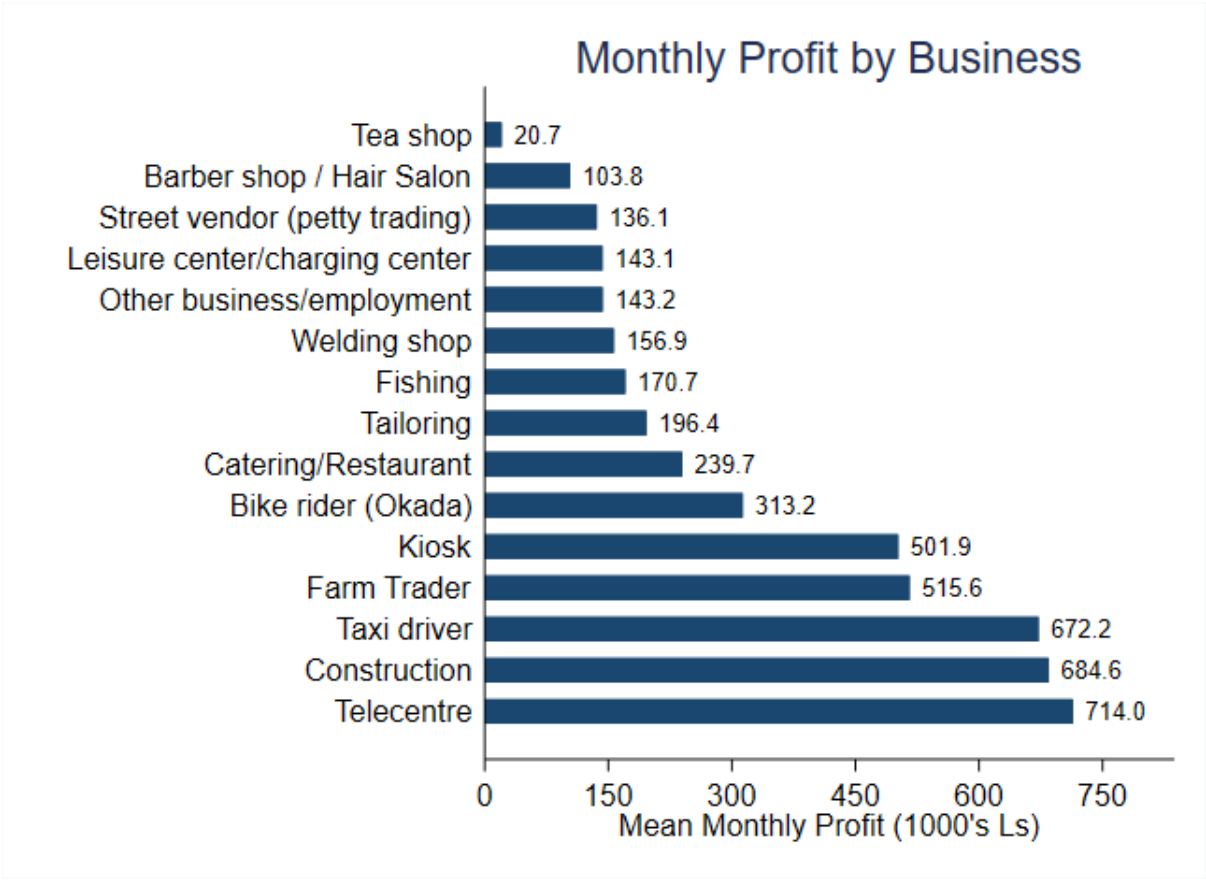

Figure 8: Monthly profits by business type

While Table 9 reports that a fifth of all self-employed businesses use electricity, Figure 9 below shows that electricity is not often put to productive use. 85 percent of businesses who use electricity report that they use electricity for lighting. A considerable amount of businesses report using electricity for freezing (30 percent) or refrigeration (11 percent), but it is unclear to what extent this use of electricity can really be considered productive. If freezing and refrigeration were being used to transport agricultural products to market, this would increase farm-gate prices for famers and could be considered a "productive use". However, to the extent that refrigeration is being used to cool drinks, it might slightly modify consumption patterns, but is not likely to be significantly improving economic production in rural economies. Given the lack of in-country cold chain, it seems likely refrigeration and freezing is being used for the latter rather than the former. Beyond lighting and cooling, electricity is mainly used for entertainment and communication, with 15 percent of businesses charging phones, 12 percent powering televisions, and 11 percent powering radios. Figure 10 shows differences in electricity usage between treatment and control. We see that more self-employed businesses who use electricity use it on productive technologies such as freezers, refrigerators, and chargers. We find that these differences are statistically significant. The difference in difference estimation strategy controls for initial differences in electricity usage levels and compares the *rates of change* of electricity usage in treatment vs control communities

In Focus Group Discussions, the most common expectations for businesses following electrification was for fridges and freezers. Respondents stated that they would use fridges and freezers for 'kukri' businesses to preserve food for longer; to bring fish and other food to town to sell; and to sell cold drinks. Not having enough money to invest was stated as a major impediment to establishing a business, even after electrification. In some less remote villages, the range of business ideas was broader, and included laminating, slaughterhouses, mechanic garages, rice mills, and fruit processing. There was also an expectation that there would be more businesses selling wiring and lights.

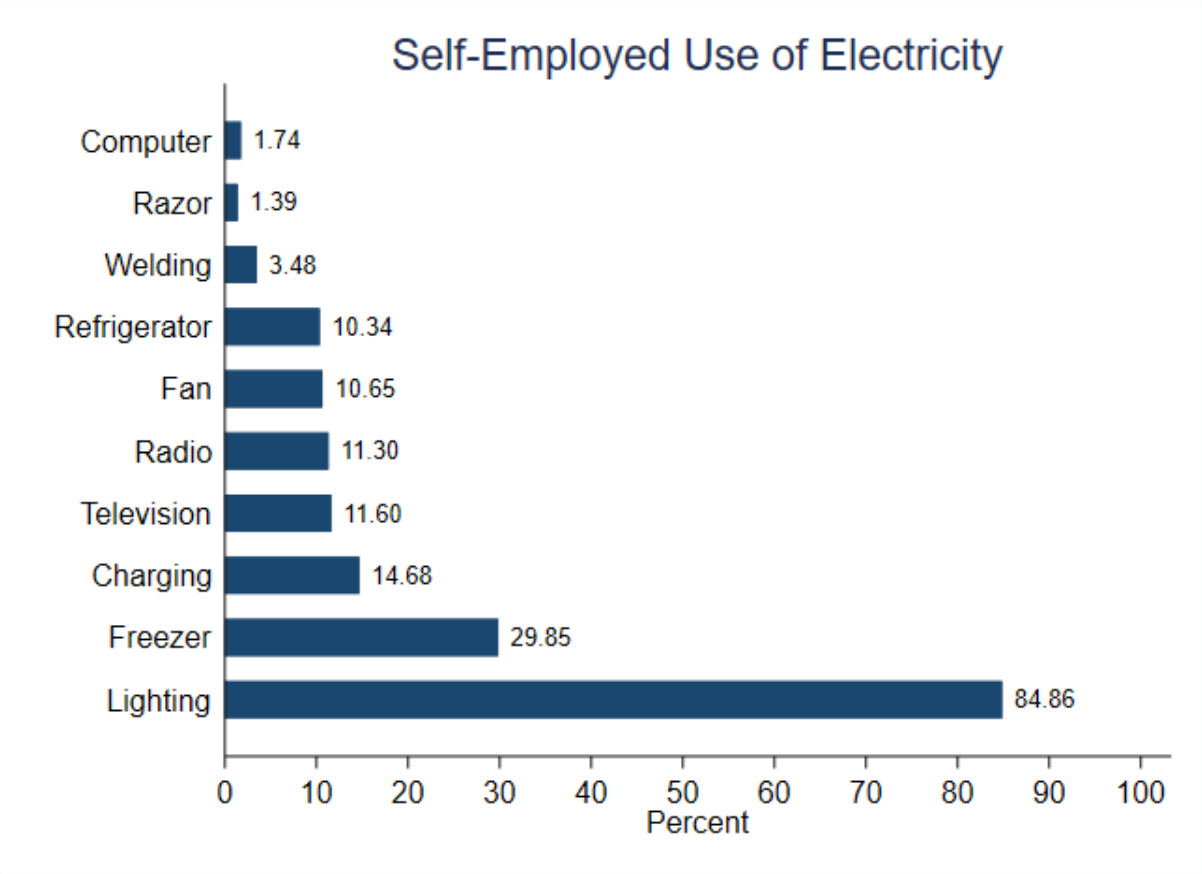

Figure 9: Self-Employed use of Electricity

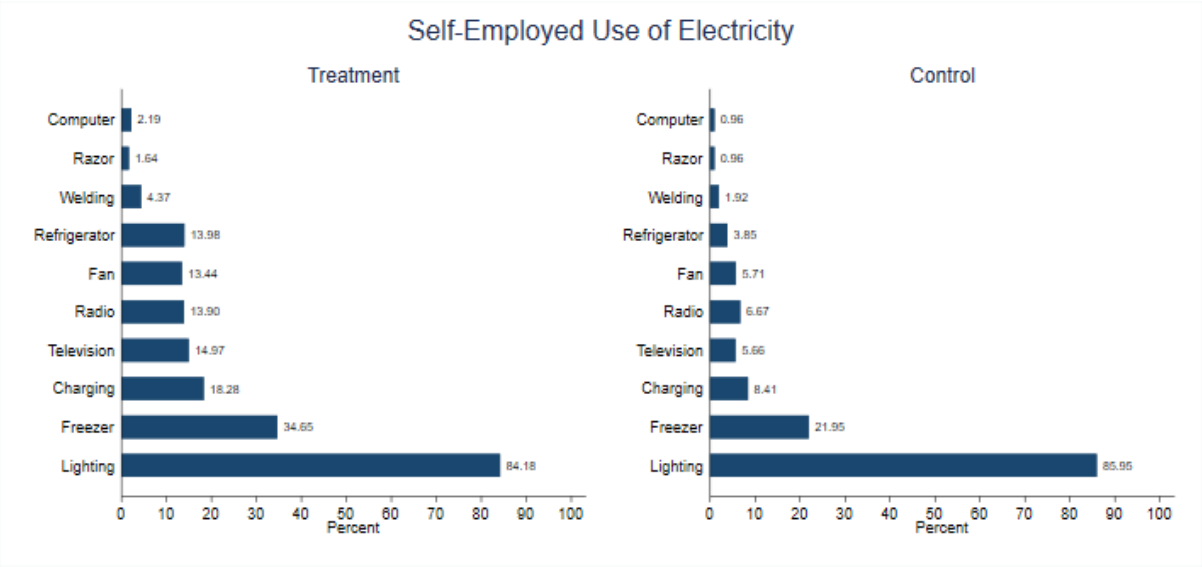

Figure 10: Self-Employed use of electricity by treatment group

While on average self-employed individuals do not claim much profit, the success of a business differs considerably by gender. Figure 11 reports business profits by gender. The mean profit for men is about 469,000 SLL per month. Women report a profit of 184,800 SLL per month, which is significantly less than men. This can be further explained by the types of businesses that women run.

The ways in which employment patterns differ by gender may shed some light on the substantial gendered differences in self-employment profits. Figure 12 shows that women are more likely to respond that they are self-employed (35 percent) compared to men (29 percent), but women are less likely to take up outside employment (3.1 percent) than men (12.8 percent). While men and women report working the same number of average hours in self-employment (Figure 13), their forms of self-employment differ. Figure 14 shows that women are much more likely to work as petty traders (52 percent) than men (16.5 percent), and that men are much more likely to work in construction or as bike riders. Self-employed women are more likely to work as a farm trader, own a kiosk, and run a catering business or a restaurant while men are more likely to own a construction business, be a bike rider, tailor, fisherman, own a charging centre, telecentre, as well as a tea shop. As we saw in Figure 7, the types of business that women are more frequently involved in— such as petty trading, running a kiosk, or being a farm trader— are less profitable businesses on average.

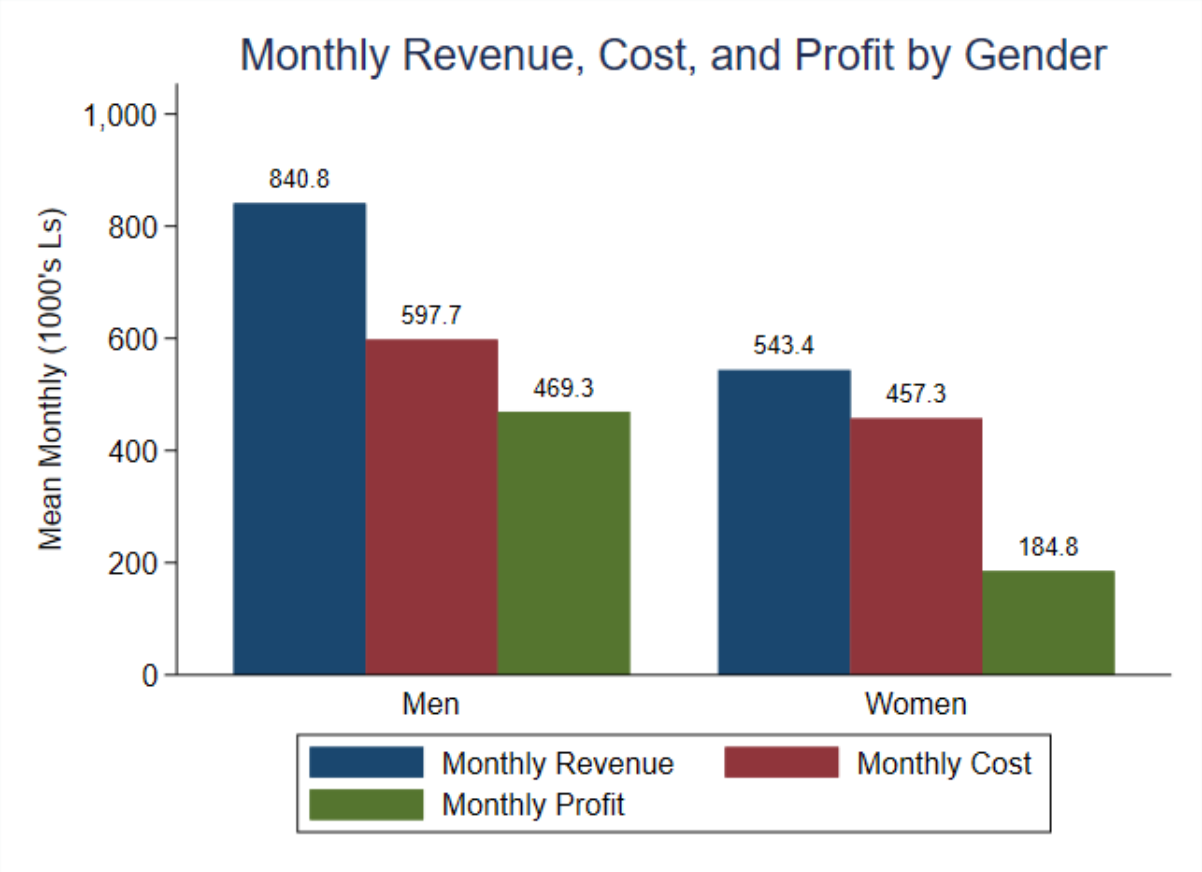

Figure 11: Revenue, Cost, and Profit by gender

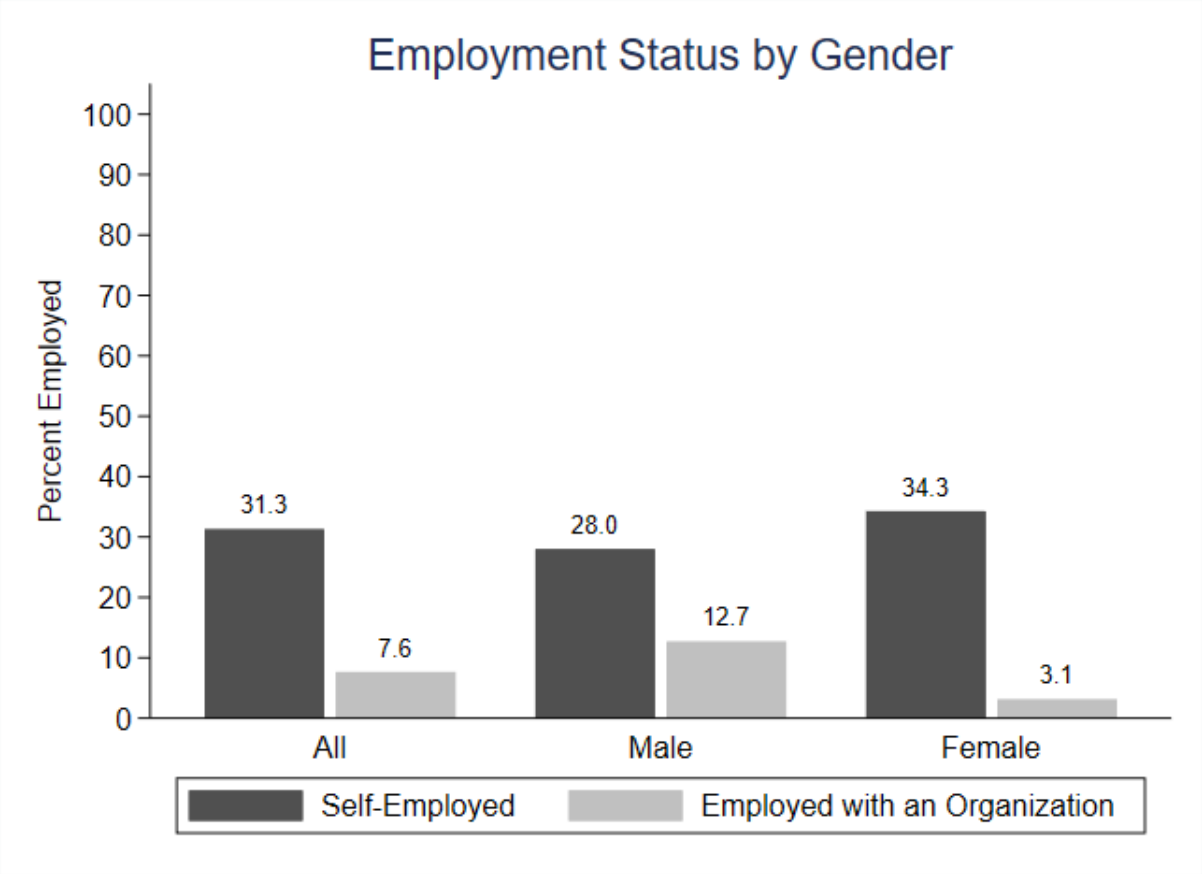

Figure 12: Employment Status by Gender

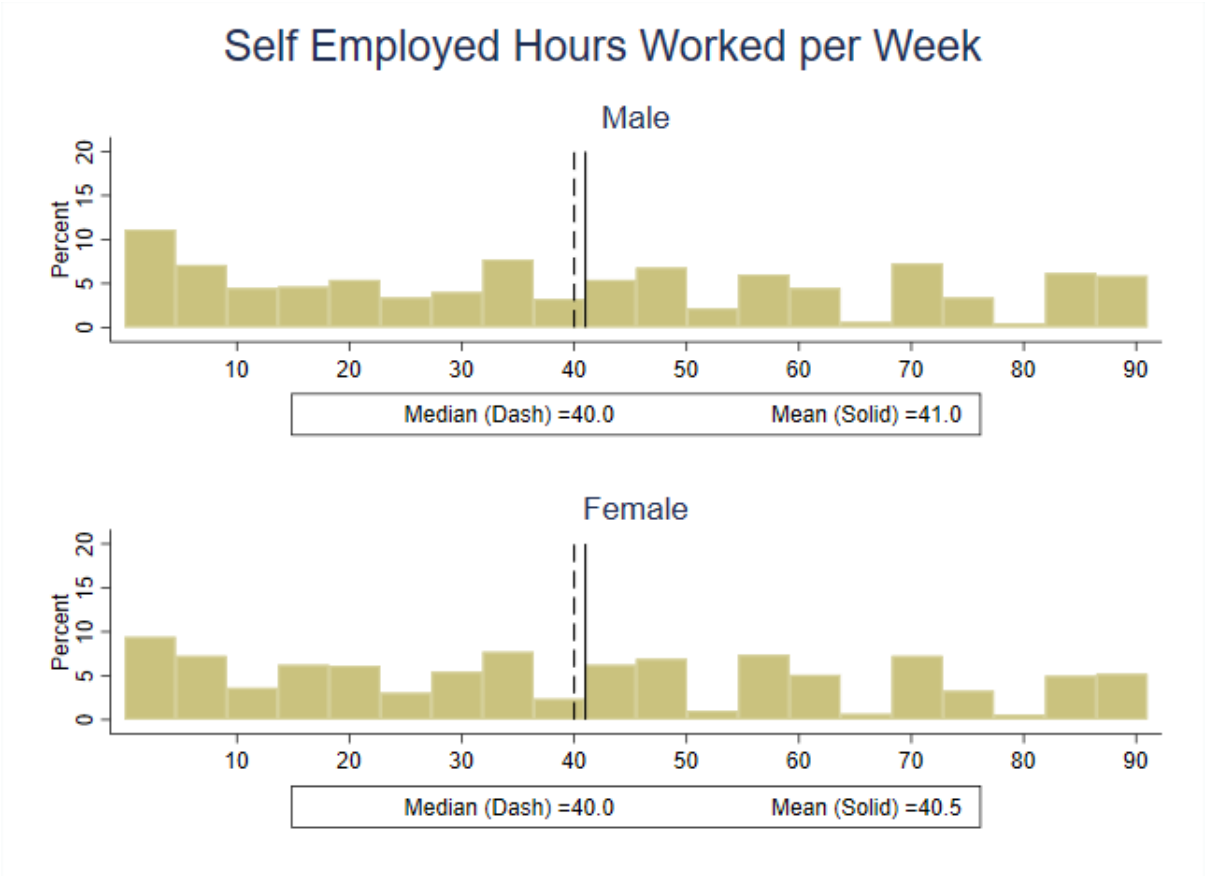

Figure 13: Self-Employed Hours Worked per week by gender

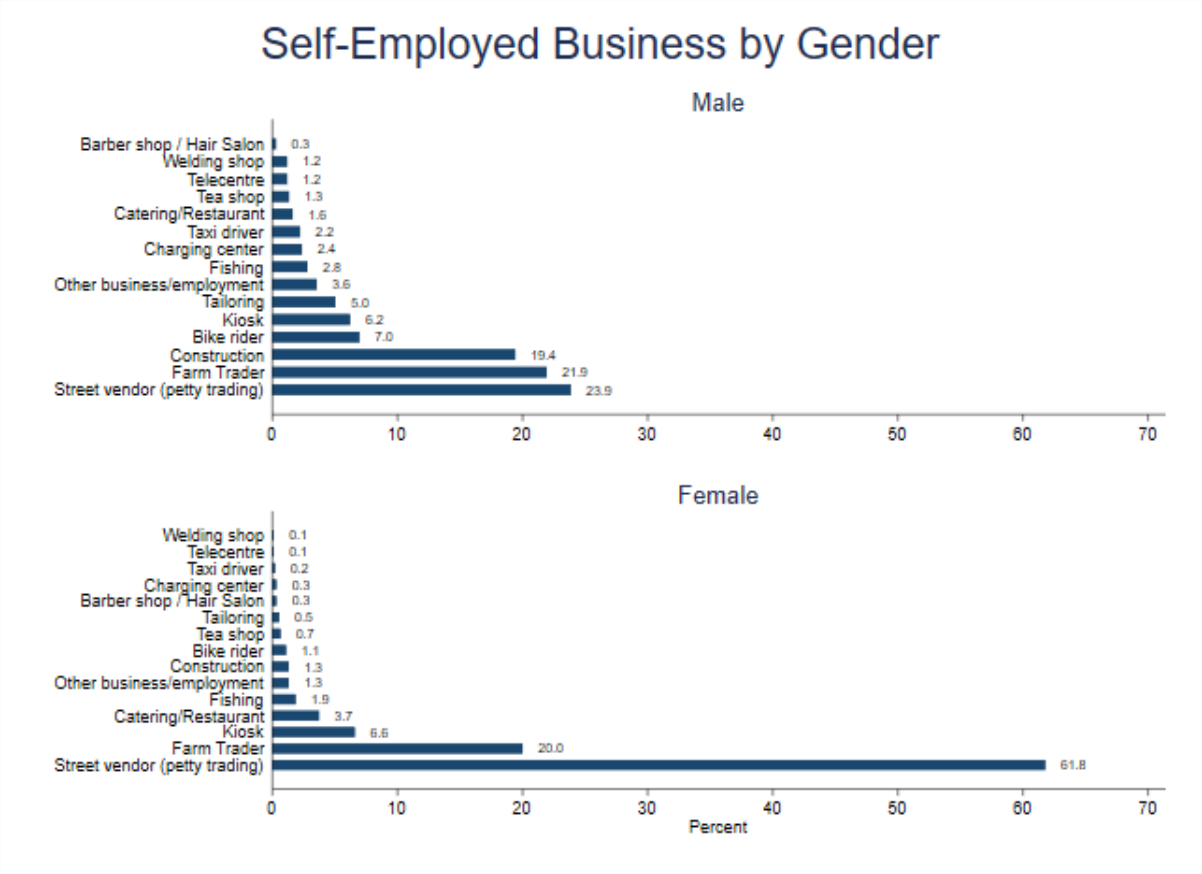

Figure 14: Self-employed business type by gender

Figure 15 shows that employment patterns also differ by disability status. People with disabilities are less likely to be self-employed and less likely to work for an outside organization. This pattern is consistent across nearly all disability sub-categories.

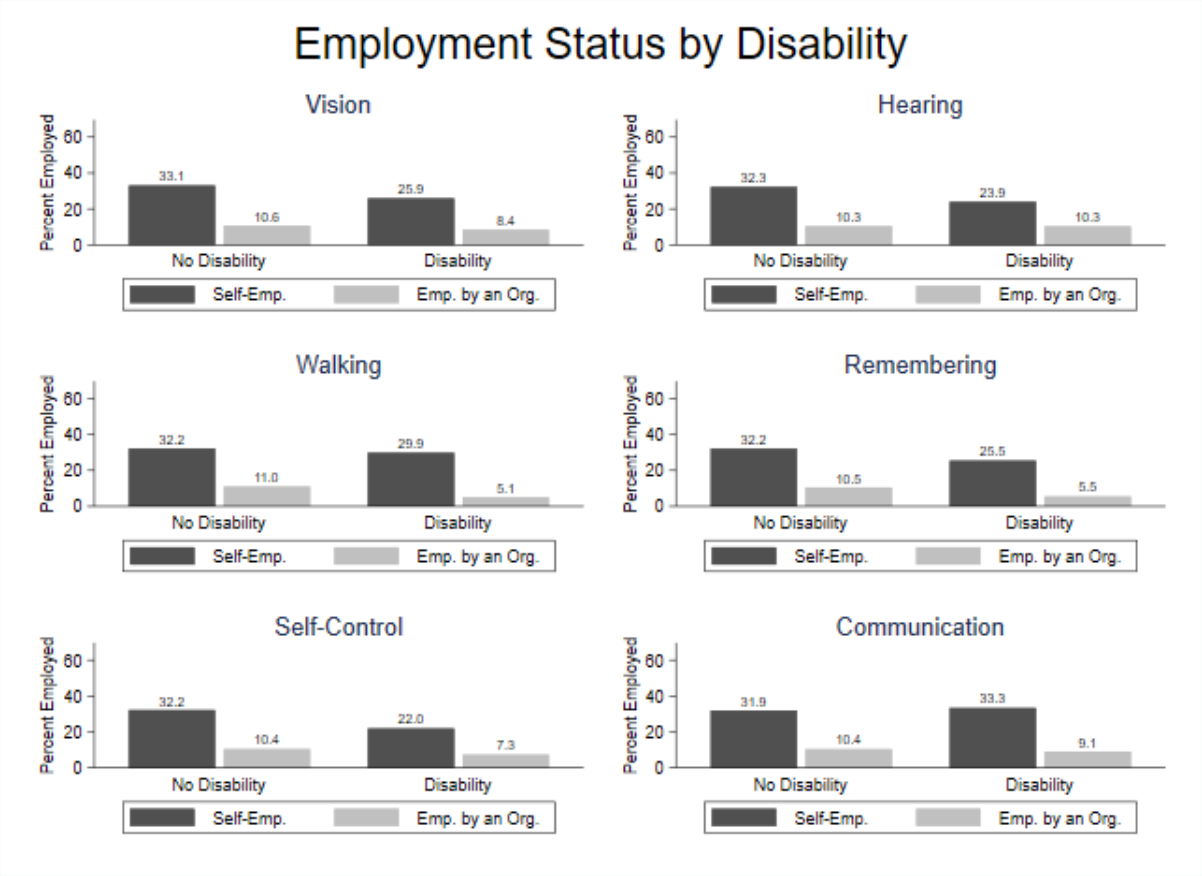

Figure 15: Employment Status by Disability

Table 10 shows how individuals in mini-grid communities (treatment) and non-mini-grid communities (control) differ across several important non-agricultural employment variables. We find no statistically significant differences in baseline levels of the number of hours worked per week in self-employment, the requirements of electricity in self-employment, average business revenue and costs, or the average salary earned at formal organizations. At baseline, individuals in treatment communities are nearly 10 percent more likely to be self-employed and are about 3.5 percent more likely to have outside employment with an organization. Figure 16 shows the breakdown of self-employed business type by treatment status. While our difference-in-difference estimation strategy can account for these baseline differences, it is important to note them.

Table 10: Balance Table: Non-Agricultural Employment Variables for Mini-grid Sites and Non-Mini-grid Sites

Variables	Control	Treatment	(1) vs. (2)
Self-Employed and owns a business	0.269	0.359	-0.090***
	(0.020)	(0.018)	(0.027)
Hours worked at own business in a typical week	40.615	40.798	-0.183
	(1.553)	(1.541)	(2.178)
Own business requires electricity	0.178	0.227	-0.049
	(0.028)	(0.030)	(0.041)
Monthly Revenue from own business	526.120	603.951	-77.830
	(75.754)	(54.293)	(92.797)

Monthly Cost from own business	485.410	521.974	-36.564
	(36.855)	(44.406)	(57.458)
Employed in a formal organization	0.058	0.095	-0.037***
	(0.006)	(0.010)	(0.012)
Net salary from formal organization	875.537	855.898	19.639
	(145.990)	(121.110)	(188.984)
N	2584	2488	5072

This table shows a balance test between treatment and control for the non-agricultural variables. Standard errors are clustered at the village level. *p<.1 **p<.05 ***p<.01

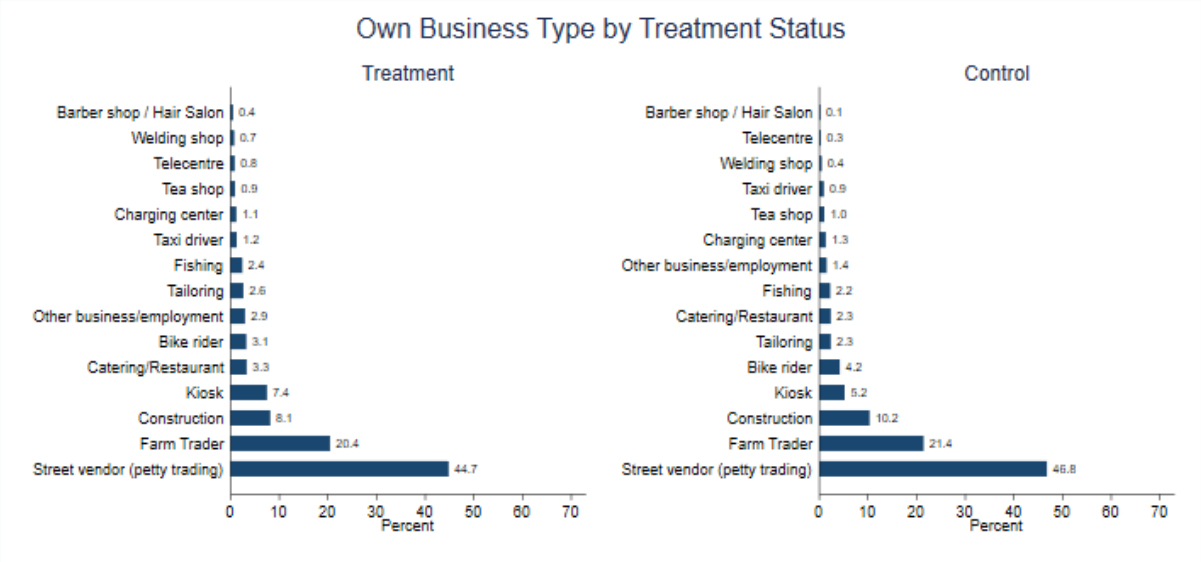

Figure 16: Self-Employed Business by Treatment Status

3.1.3 Livestock

Livestock is sometimes referred to the "savings account" of the rural economy. If electrification raises incomes – either through agricultural production or non-agricultural employment – household may decide to invest some of this extra income in livestock. Therefore, it is essential that we capture baseline levels of livestock in treatment and control communities. We catalogue all animals owned in the household - ownership defined as the right to kill or sell the animal. We also quantify what share of the household's animals are (at least) jointly shared by women.

Table 11 shows that about 36 per cent of the sample household own at least 1 animal. The median household owns 3 animals, and the mean average number of animals owned by a household is 6.1 (See figure 17). Of course, which the type of animal owned has an impact on its value. Figure 18 breaks down animal ownership by type of animal. Nearly 80 percent of households own chickens (a low value animal), 40 percent of households own at least one goat, and 24 percent of households own at least one sheep. Cows, the highest value livestock, are owned by less than 4 percent of households. By breaking down livestock by animal type, we can untangle not only if electrification is changing total livestock ownership, but also if livestock is changing the composition of household livestock towards higher value animals.

Table 11: Summary Statistics for Livestock Ownership

	n	Mean	Median	Min.	Max.
Do you or any of your household members own any livestock?	3253	0.65	1.00	0.00	1.00
Number of livestock owned (All Households)	3249	6.29	3.00	0.00	124.00
Number of livestock owned (Own livestock only	2122	9.63	7.00	1.00	124.00
Chick	2126	0.79	1.00	0.00	1.00
Goat	2126	0.41	0.00	0.00	1.00
Sheep	2126	0.24	0.00	0.00	1.00
Pig	2126	0.01	0.00	0.00	1.00
Duck	2126	0.05	0.00	0.00	1.00
Cow	2126	0.04	0.00	0.00	1.00
Observations	3253				

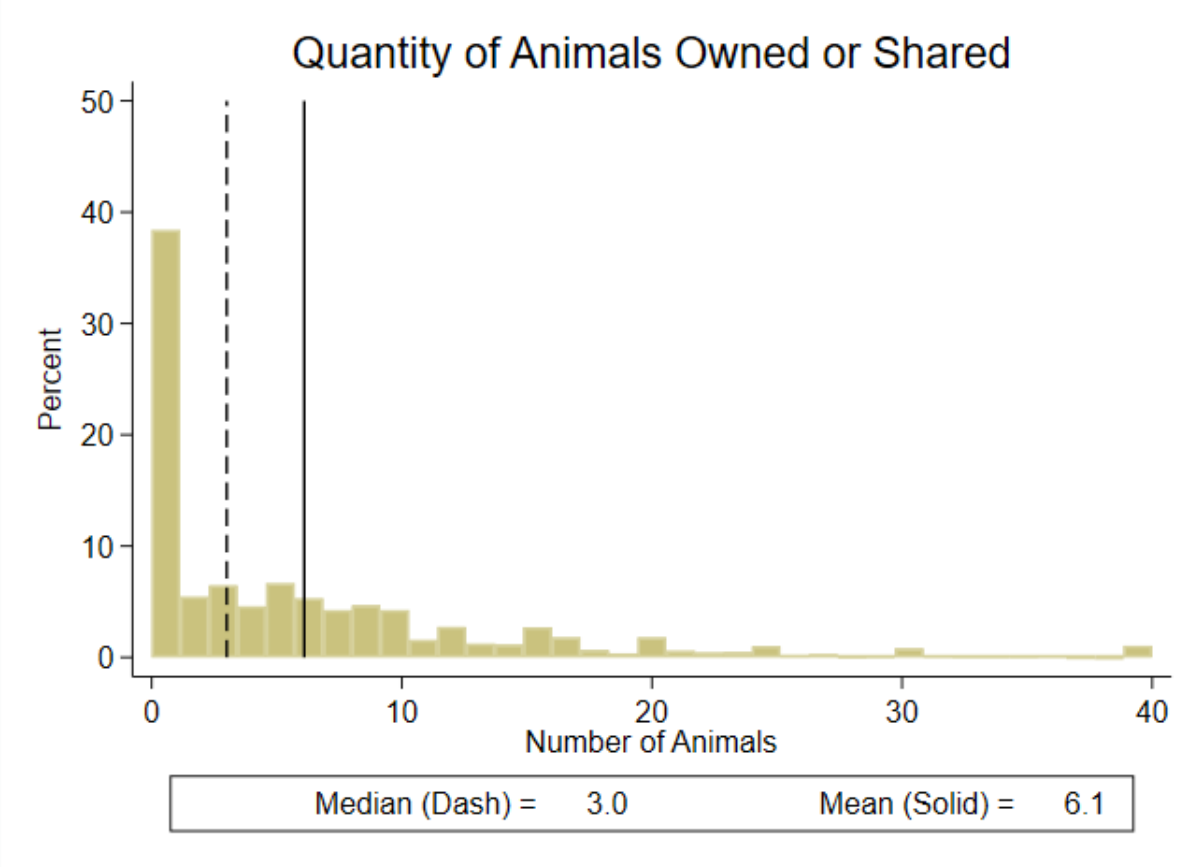

Figure 17: Quantity of Animals Owned or Shared

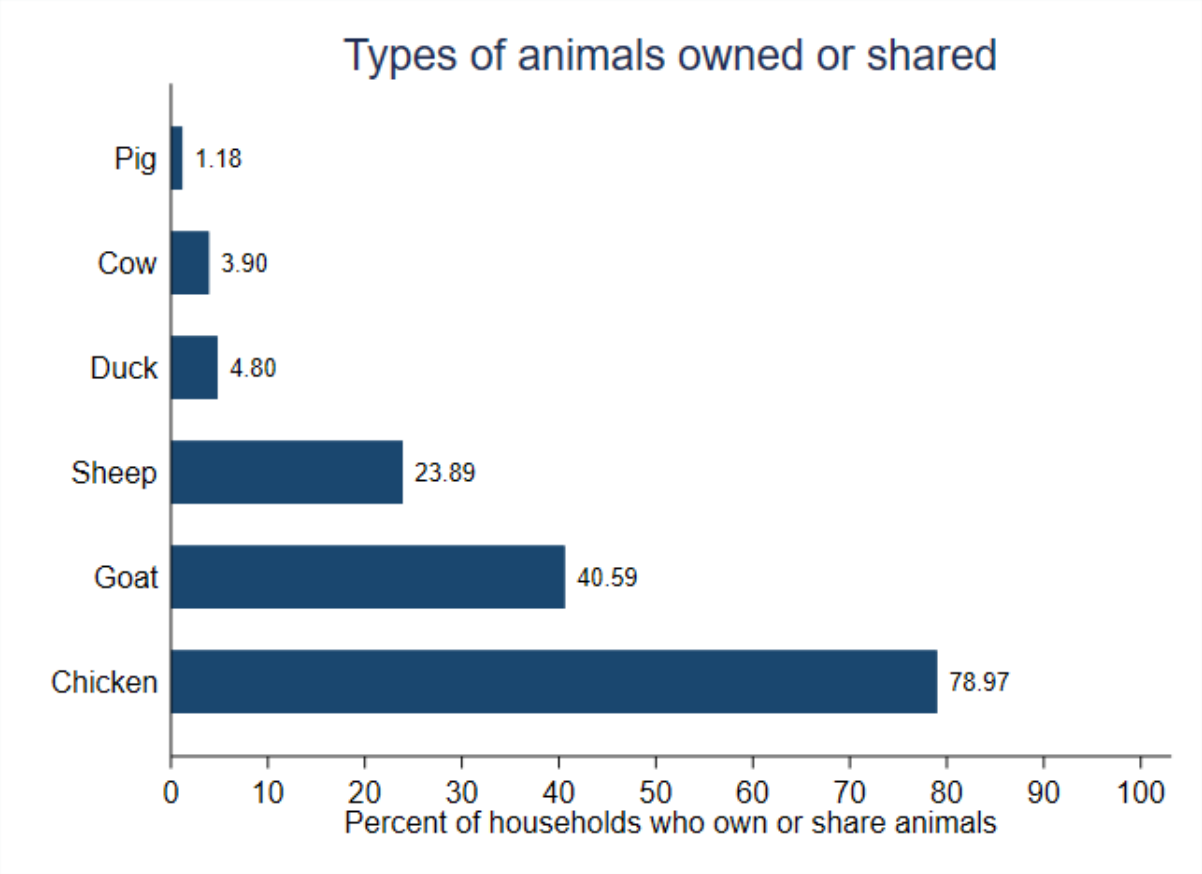

Figure 18: Types of Animals Owned or Shared

Figure 19*:* Livestock Ownership by Disability Status

Table 12: Balance Table: Livestock

	Control	**Treatment**	**(1) vs. (2)**
Do you or any of your household members own any livestock?	0.648	0.659	-0.011
	(0.022)	(0.019)	(0.029)
Number of livestock owned (All Households)	5.762	6.800	-1.039**
	(0.332)	(0.352)	(0.481)
Number of livestock owned (Own livestock only)	8.904	10.326	-1.422**
	(0.392)	(0.403)	(0.559)
Chicken	0.802	0.778	0.024
	(0.027)	(0.022)	(0.034)
Goat	0.372	0.439	-0.067*
	(0.029)	(0.026)	(0.039)
Sheep	0.217	0.260	-0.043
	(0.023)	(0.024)	(0.033)
Pig	0.010	0.014	-0.004
	(0.004)	(0.004)	(0.006)
Duck	0.047	0.049	-0.002
	(0.009)	(0.009)	(0.013)
Cow	0.030	0.046	-0.016
	(0.014)	(0.016)	(0.021)
N	**1601**	**1650**	**3251**
This table shows a balance test between treatment and control for the non-agricultural variables. Standard errors are clustered at the village level. *p<.1 **p<.05 ***p<.01			

Figure 19 compares the average number of animals owned in households where the household head suffer from a disability to households where the household head does not suffer from a disability. Average livestock ownership is nearly identical in disabled and non-disabled households across all disability domains.

Table 12 reports differences in livestock ownership between treatment and control villages. Treatment communities have on average one more animal per household than control communities; this difference is statistically significant. When we look at breakdown of livestock ownership by animal type, this difference is being driven largely by differences in goat ownership. Households in treatment communities are 6.7 percentage points (18 percent) more likely to own goats than households control communities.

While there are differences in livestock ownership between treatment and control communities at baseline, this does bias our results. The difference in difference estimation strategy controls for initial differences in livestock levels and compares the *rates of change* of livestock ownership in treatment vs control communities.

3.1.4 Household Assets

Figure 20 shows ownership of electrified assets. Communication and entertainment items dominate the list of currently owned assets. The most popular electrified assets are phones (54 percent) and radios (49 percent), followed by DVD equipment (9 percent), televisions (7 percent), and stereos (3 percent). Baseline ownership of productive assets is low and the ownership of all productive assets is below three percent, such as freezers (2.9 percent), sewing machines (2.4 percent) and electric stoves (0.15 percent).

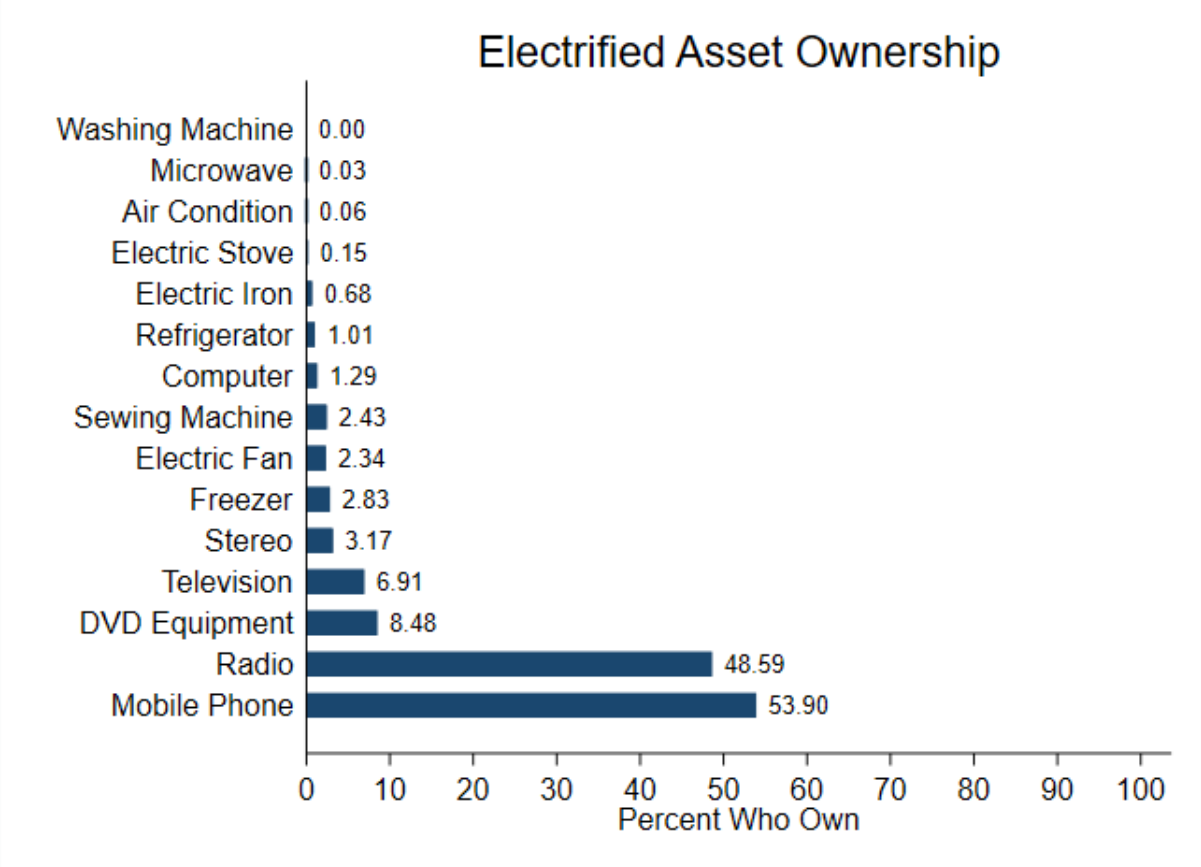

Figure 20: Ownership of Electrified Assets

Table 13: Balance Table: Ownership of Electrified Assets

	Control	Treatment	(1) vs. (2)
Washing machine	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Microwave	0.001	0.000	0.001
	(0.001)	(0.000)	(0.001)
Air conditioner	0.001	0.000	0.001
	(0.001)	(0.000)	(0.001)
Stove (electric)	0.001	0.002	-0.001
	(0.001)	(0.001)	(0.001)
Iron (electric)	0.004	0.009	-0.005*
	(0.002)	(0.002)	(0.003)
Refrigerator	0.006	0.015	-0.009**
	(0.002)	(0.003)	(0.004)
Computer	0.008	0.018	-0.009*
	(0.004)	(0.003)	(0.005)
Sewing Machine	0.021	0.027	-0.006
	(0.004)	(0.004)	(0.006)
Electric fan	0.011	0.035	-0.024***
	(0.003)	(0.005)	(0.006)
Freezer	0.016	0.041	-0.025***
	(0.004)	(0.005)	(0.007)
Stereo system	0.021	0.042	-0.021**
	(0.005)	(0.008)	(0.009)
Television	0.045	0.093	-0.048***
	(0.007)	(0.012)	(0.013)
Video/DVD equipment	0.059	0.110	-0.050***
	(0.009)	(0.013)	(0.016)
Radio	0.430	0.539	-0.109***
	(0.022)	(0.020)	(0.029)
Mobile phone	0.465	0.610	-0.145***
	(0.025)	(0.024)	(0.034)
N	1601	1650	3251

Standard errors are in parentheses. Column 3 shows the difference in means. Stars indicate significance level.
*<.10 **<0.05 ***<0.01

While the overall ownership of electrified assets is low, households in treatment communities tend to have slightly higher ownership rates. Substantively, the largest difference between households in treatment communities and households in control communities is in the domain of communication and entertainment. Households in treatment communities are 14.5 percentage points more likely to own mobile phones, 11 percentage points more likely to own a radio, 5 percentage points more likely to own video/DVD equipment, 4.8 percentage points more likely to own a television and 2.1 percentage points more likely to own a stereo system. The gap between treatment and control communities for productive assets is substantively smaller. Treatment households are 2.5 percentage points more likely to own a freezer, .9 percentage points more likely to own a refrigerator, .5 percentage points more likely to own an electric iron and .9 percentage points more likely to own a computer.

As noted in the methodology section, it is possible that differences in ownership of electrified assets are due to treatment communities increased expectations about future access to electricity. That said, we suspect that this baseline difference is *not* due to the effects of the RREP program, but existing baseline wealth differences between RREP sites and non-RREP sites. In line with this interpretation, we note that treatment communities are more likely to have higher levels livestock ownership and more likely to run their own business, indicators of wealth that are less likely to be influenced by *expectations of future access to electricity.* Again, baseline differences in wealth between treatment and control communities will not bias are results, so long as wealth indicators in treatment and control communities would have changed at similar rates in absence of RREP.

In Focus Group Discussions, it was found that smaller villages were less likely to have a resident who owned a generator. Where generators were owned, they were often used for 'cinemas' to show sports games, air compressors, or fridges. Maintenance was main concern for generator owners, as they often had to travel to a large city to service it at a high cost.

When asked about what people were most looking forward to when their communities were electrified there was a general expectation that businesses would open but not always a clear articulation of how this would manifest itself. Many focus group respondents stated that they were most looking forward to watching television and powering their DVD players. This was stated as a reason to have closer families and for children to stay at home more often.

3.2 Health Outcomes

This section expands upon the results for health indicators and outcomes measured in the Household Survey. This report only presents indicators being measured through household questionnaire. However, administrative data is being collected from CHCs throughout the duration of the evaluation and changes in indicators collected through administrative data will be monitored and presented in end line report.

3.2.1 Acute Respiratory Infection

Table 14 reports summary statistics of health indicators. 22 percent of respondents suffered from symptoms of Acute Respiratory Infections (ARI) in the past 30 days. 33 percent of those who suffered ARI symptoms sought treatment at the community health centre.

Table 14: Summary Statistics of Health Indicators

	N	Mean
Has suffered from malaria in the past 30 days	5180	0.41
Sought treatment for malaria at Primary Health Clinic	2100	0.49
Has suffered from ARI in the past 30 days	5171	0.22
Sought treatment for ARI at Primary Health Clinic	1157	0.33
Has suffered from cataracts/dry eyes in the past 30 days	5170	0.06
Sought treatment for cataracts/dry eyes at Primary Health Clinic	322	0.32
Observations	5180	

Figure 21 shows infections suffered in the past month, disaggregated by age. It shows that children under the age of 5 (30 percent) are more likely to suffer from symptoms of ARI than respondents over 5 (17.5 percent). There are no differences in these patterns across gender.

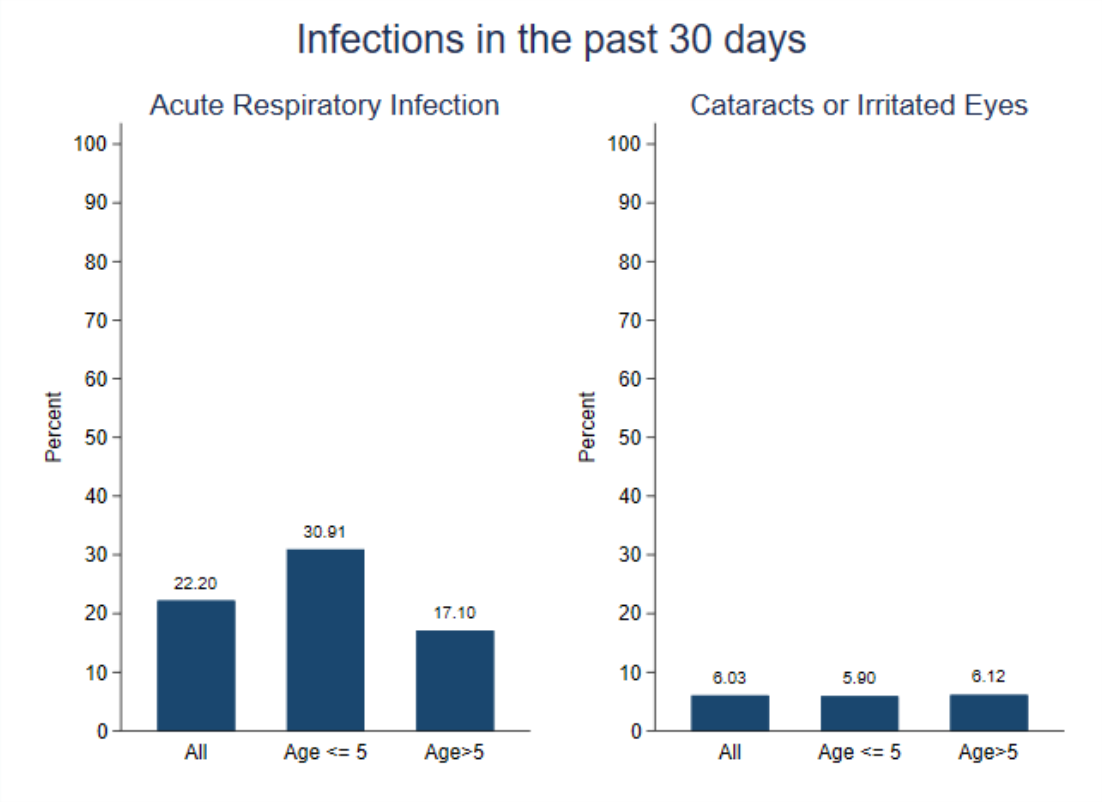

Figure 21: Infections by age

The figure above shows infections reported in the past month by age. We see that nearly a quarter of our respondents have suffered from an acute respiratory infection in the past month. Children under the age of 5 are most susceptible to respiratory infections. We see again that children are once again the most susceptible when it comes to cataracts and dry eyes.

3.2.2 Irritated Eyes

Table 11 shows that 6 percent of respondents suffered from difficulty with eyesight in the past 30 days. There is no difference across age or gender (Figure 14). 32 percent of those who suffered these symptoms sought treatment at the community health centre.

3.2.3 Disabilities

Table 12 reports respondents who answered that they have at least some difficulty day-to-day tasks such as communication, hearing, remembering, seeing, and exhibiting self-control. These questions were measured using the Washington Group Disability Questions. The Washington Group Short Set of Disability Questions is effective at identifying individuals in a population with disabilities, but it does not go into a lot of detail about psycho-social disabilities. These questions allowed the evaluation team to gain enough information on disability to disaggregate it with other indicators in the survey. The findings provide a

broader picture of the kind of disabilities that exist in Sierra Leone. Of the 7,846 respondents surveyed, 2 percent report having difficulty hearing, remembering, or with self-control. 8 percent of respondents report difficulty seeing, and 6 percent report difficulty walking. Overall, 15 percent of individuals report having at least one disability (note that each individual can suffer from more than one disability).

Table 15: Disabilities - Summary Statistics

	n	Mean
Difficulty Communicating	7610	0.02
Difficulty Hearing	7597	0.02
Difficulty Remembering	7597	0.02
Difficulty Seeing	7606	0.08
Difficulty Self-Control	7591	0.02
Difficulty Walking	7594	0.06
Has any disability	7610	0.15
HH with member who is disabled	3252	0.32
Observations	7846	

32 percent of the households in our sample reported having a member who is disabled. There appears to be little systematic differences in disabilities across gender (Figure 15). We also see that the most common self-reported disabilities are difficulty seeing and difficulty in mobility.

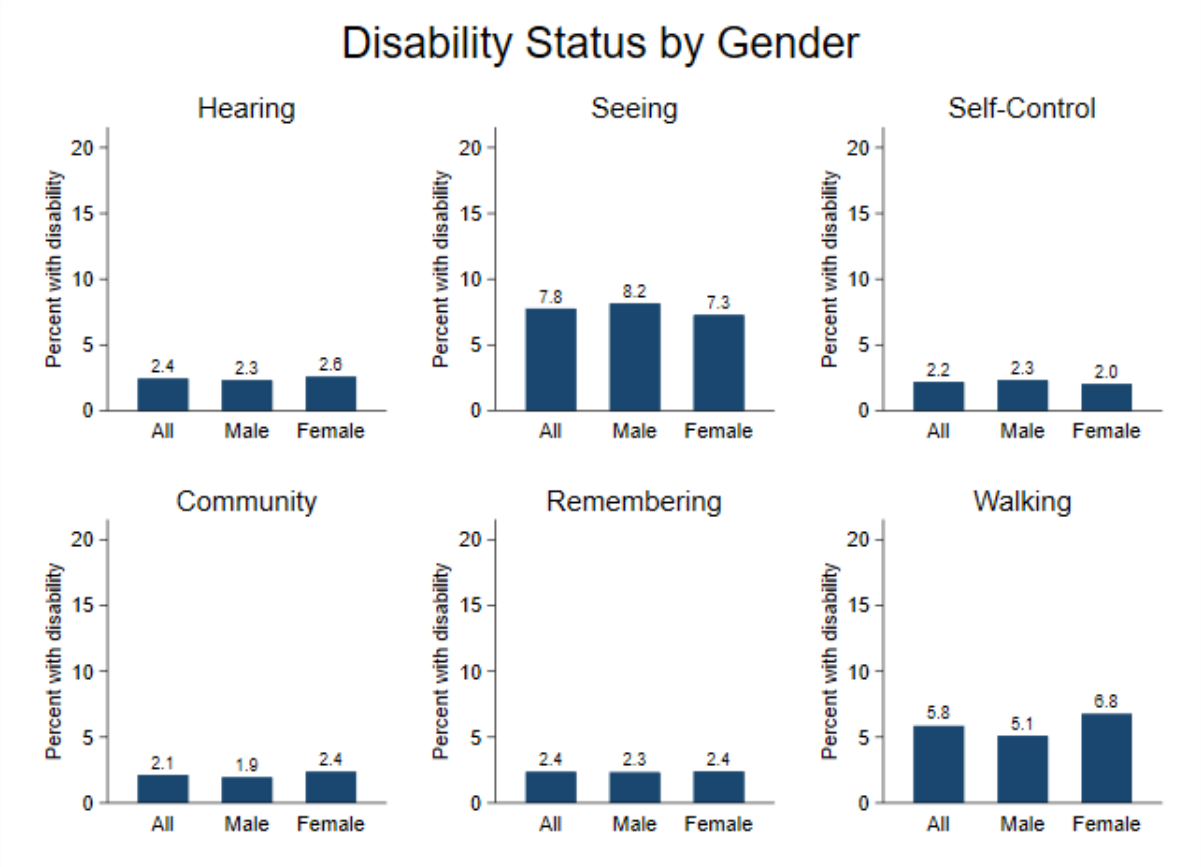

Figure 22: Disability Status by Gender

Figure 22 disaggregates disability by gender and type of disability. The biggest disability in our sample is related to sight. 7.7 percent of our sample reported having trouble with sight. 8.1 percent of men reported having trouble seeing compared to 7.3 percent women. More women (6.6 percent) have a disability related to mobility and walking compared to men (5.1 percent).

Table 16: Balance Table: Disability Status for Mini-grid Sites and Non-Mini-grid Sites

	Control	Treatment	Difference in Means
	(1)	(2)	(3)
Difficulty Communicating	0.021	0.022	-0.001
	(0.004)	(0.004)	(0.005)
Difficulty Hearing	0.020	0.029	-0.009**
	(0.003)	(0.003)	(0.004)
Difficulty Remembering	0.017	0.030	-0.012***
	(0.003)	(0.003)	(0.004)
Difficulty Seeing	0.076	0.079	-0.004
	(0.006)	(0.005)	(0.008)
Difficulty Self-Control	0.020	0.024	-0.004
	(0.003)	(0.003)	(0.004)
Difficulty Walking	0.050	0.067	-0.017**
	(0.004)	(0.006)	(0.007)
Has any Disability	0.140	0.165	-0.025**
	(0.008)	(0.009)	(0.012)
HH with Member who is Disabled	0.297	0.338	-0.041*
	(0.015)	(0.017)	(0.023)
N	3762	3842	7604

Standard errors are in parentheses. Column 3 shows the difference in means. Stars indicate significance level. *<.10 **<0.05 ***<0.01

3.2.4 Other Disease Prevalence

Table 14 shows that 41 percent of respondents suffered from symptoms of malaria in the past 30 days. Half of those who suffered from malaria like symptoms sought treatment at the community health centre.

3.2.5 Neo-Natal & Under 5 Mortality

Table 17 shows that 19 percent of households had at least one woman that gave birth in the past year. 5 percent of those households contained a pregnancy that ended in a stillbirth. Of households currently living with children, 7 percent had a child under 5 that died in the past year.

Focus Group Discussions revealed that respondents were concerned about their children being bitten by snakes when they are outside during the dark. Several respondents mentioned that when there were streetlights their children would be safer.

3.2.6 Maternal Mortality

Table 17 shows that on average 2 percent of households reported that a woman died during pregnancy or delivery over the past year. 5 percent of pregnancies ended in a stillbirth.

Table 17: Maternal Health and Child Mortality

	(1)				
	n	Mean	Median	Min.	Max.
Woman in HH gave birth to a child in the past year	3252	0.19	0.00	0.00	1.00
Pregnancy ended in a stillbirth	620	0.05	0.00	0.00	1.00
Child under 5 years old died in the past year	1934	0.07	0.00	0.00	1.00
Woman in HH died during pregnancy in the past one year	3248	0.02	0.00	0.00	1.00
Observations	3253				

CHC staff in treatment villages stated that having light has made a big difference to the care that they can provide. First, there is light for them to see patients; and second, when people visit at night, they do not have to supply their own batteries. One CHC worker said that the main difference is having light at night, which results in fewer mistakes being made particularly during childbirth. CHC staff at control villages explained that it was very difficult for them to operate at night, and that patients had to bring batteries or even candles.

Table 14 compares baseline health indicators between communities that received mini-grids through the RREP program (treatment) and selected comparison (control) communities. There are no statistically significant differences in the presented key health indicators between treatment and control communities.

Table 18: Balance Table - Health Indicators for Mini-grid Sites and Non-Mini-grid Sites

Variables	**Control**	**Treatment**	**(1) vs. (2)**
	(1)	(2)	(3)
Has suffered from malaria in the past 30 days	0.389	0.421	-0.031
	(0.025)	(0.020)	(0.032)
Sought treatment for malaria at Primary Health Clinic	0.499	0.483	0.016
	(0.018)	(0.015)	(0.023)
Has suffered from ARI in the past 30 days	0.221	0.223	-0.002
	(0.021)	(0.017)	(0.027)
Sought treatment for ARI at Primary Health Clinic	0.313	0.356	-0.043
	(0.021)	(0.021)	(0.030)
Has suffered from cataracts/dry eyes in the past 30 days	0.050	0.070	-0.019
	(0.010)	(0.008)	(0.012)

Sought treatment for cataracts/dry eyes at Primary Health Clinic	0.279	0.346	-0.067
	(0.041)	(0.041)	(0.058)
Observations	2583	2733	5316

Table 19 shows the balance comparison for health indicators by gender. The sample is mostly balanced except for the indicator for malaria. More women reported suffering from malaria in the past month than men. More women also sought treatment for malaria at a primary health clinic than men, but the difference in means is not statistically significant.

Table 19: Balance Table - Health Indicators by Gender

Health indicators by Gender	**Men**	**Women**	**Difference in means**
	(1)	(2)	(3)
Has suffered from malaria in the past 30 days	0.392	0.427	-0.035**
	(0.018)	(0.018)	(0.016)
Sought treatment for malaria at Primary Health Clinic	0.476	0.512	-0.036
	(0.016)	(0.016)	(0.023)
Has suffered from ARI in the past 30 days	0.224	0.219	0.005
	(0.015)	(0.015)	(0.013)
Sought treatment for ARI at Primary Health Clinic	0.329	0.343	-0.014
	(0.019)	(0.026)	(0.032)
Has suffered from cataracts/dry eyes in the past 30 days	0.058	0.064	-0.006
	(0.006)	(0.008)	(0.006)
Sought treatment for cataracts/dry eyes at Primary Health Clinic	0.323	0.308	0.014
	(0.034)	(0.040)	(0.046)
N	**3194**	**1986**	**5180**

3.3 Education Outcomes

Table 20 summarizes education indicators for children (6-18 years old). The enrolment rate was obtained by randomly selecting two children from the household roster, one of each gender whenever possible, to be the representative sample. On average 89 percent of the sample is enrolled in school. We also see that children spend around 7.5 hours per weeks studying at home. Table 21 breaks down these indicators by gender. We see that slightly more girls than boys are enrolled in school, but the difference is not statistically significant. The only indicator where there is a significant difference is in the hours spent studying at home in the past week, with boys reporting studying more hours than girls.

Table 20: Education Indicators for Children Ages 6-18

	count	mean	sd	median	min	max
Enrolled in School	3819	0.89	0.31	1.00	0.00	1.00
Number of days in the last week that child missed school (excluding holidays)	3411	0.27	0.91	0.00	0.00	7.00

Hours spent studying at home in the past week	3311	7.57	5.82	7.00	0.00	28.00
Observations	3819					

In table 20 above, the main educational indicators tell us that, on average, children in our sample missed .27 days of school in the last week. Despite the number of children missing school each week, we see that there is an average of around 7.5 hours a week spent studying for school. The number of hours spent studying is varying between 0 hours a week up to 28 hours a week.

Table 21: Education Indicators by Gender

	Boys	Girls	Overall	Difference in Means
Enrolled in School	0.890	0.897	0.893	-0.006
	(0.011)	(0.010)	(0.009)	(0.011)
Number of days in the last week that child missed school (excluding holidays)	0.265	0.271	0.268	-0.005
	(0.028)	(0.032)	(0.027)	(0.027)
Hours spent studying at home in the past week	7.856	7.260	7.565	0.597***
	(0.230)	(0.227)	(0.209)	(0.187)
N	2618	2488	5106	5106

Table 21 is disaggregated by gender so we can see more accurately the differences of boys and girls. On average girls are slightly more enrolled, yet they are also more likely to be missing school in the last week. However, the difference in means is very small, and neither of these differences is statistically significant. We see that the hours spent studying in the home for the past week is higher for boys than it is for girls with boys studying roughly half an hour more per week compared to girls.

3.3.1 Attendance

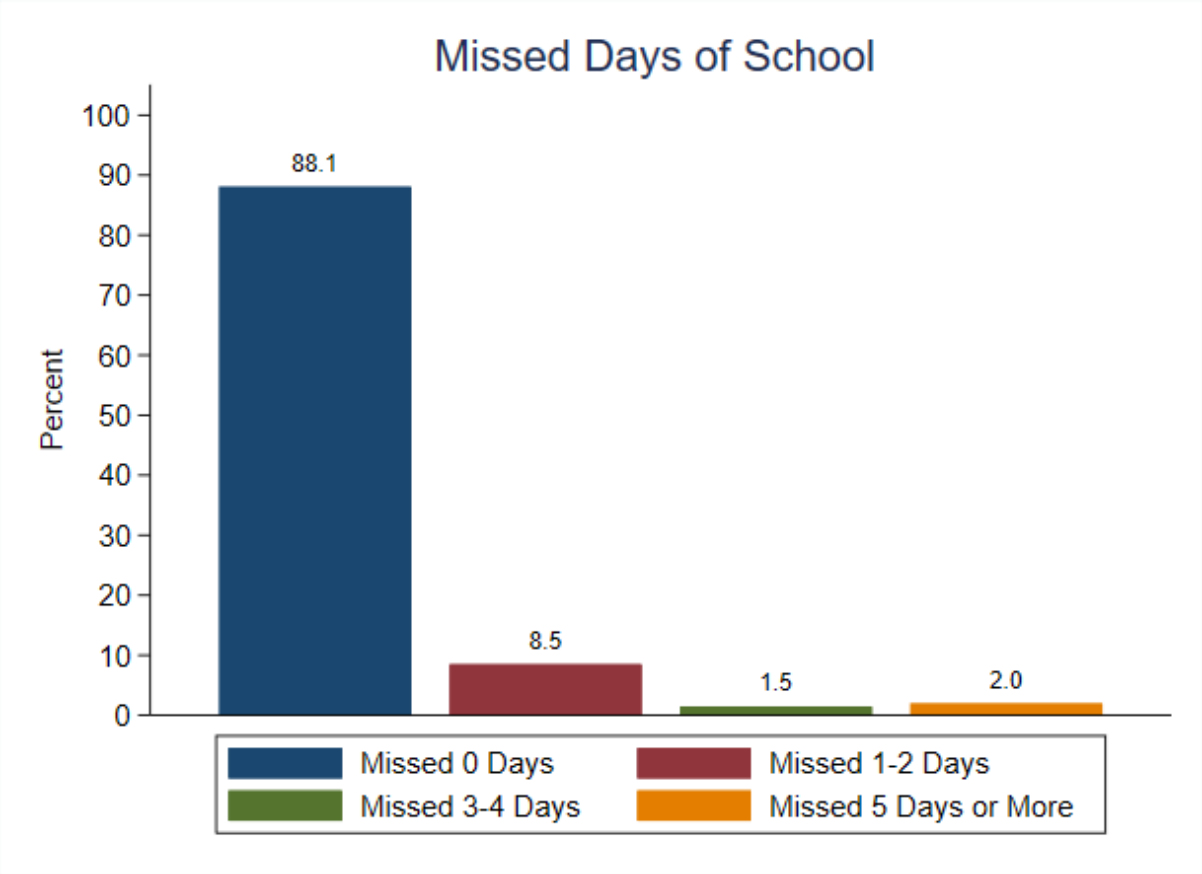

Figure 23: School Attendance

Figure 23 displays patterns of school attendance in the last week. With the observations of 3,819 children we see that there are 88 percent of children who did not miss a single day of school in the past week. 8.5 percent for respondents report their children missing 1-2 days of school. Under 4 percent missed more than two days of school. These observations come from the household survey questions about children between 6-18 years old.

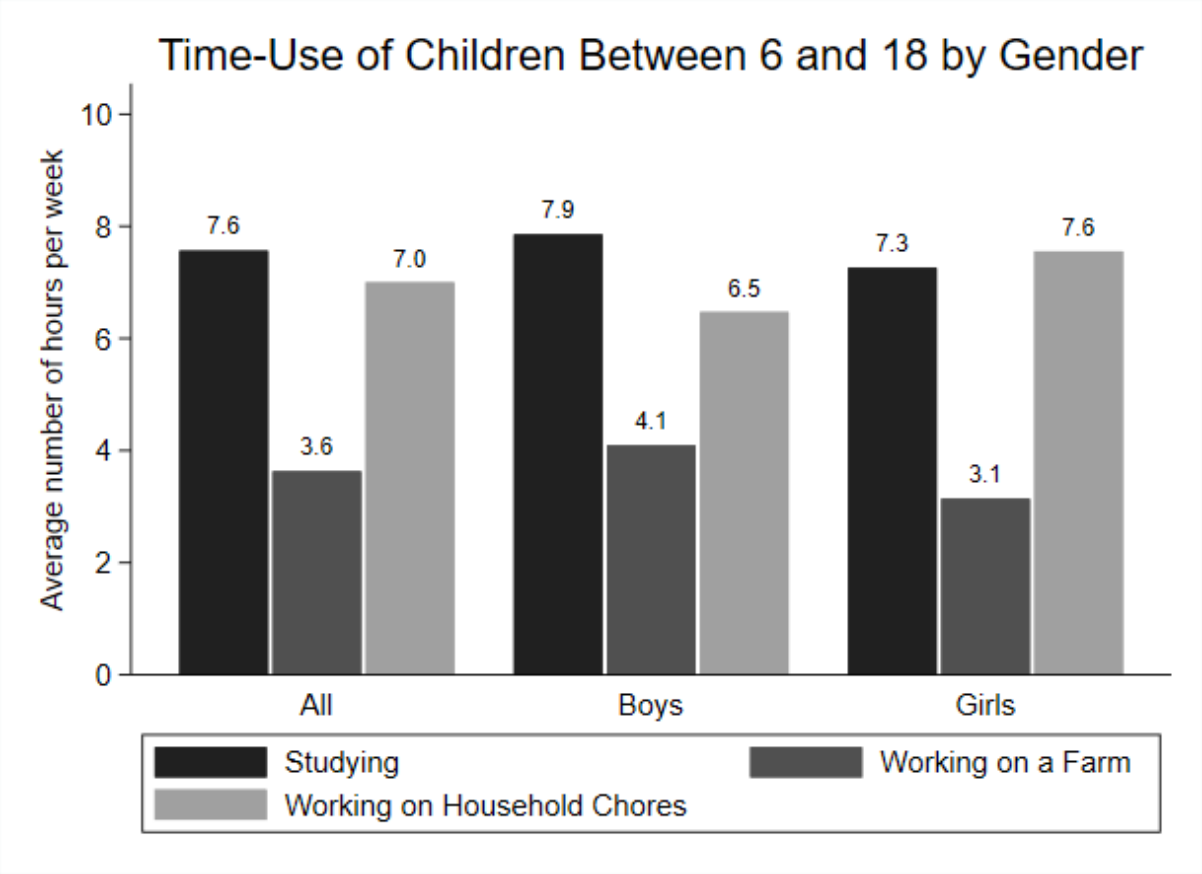

Figure 24: Time Use of children by Gender

Figure 24 explains the time-use patterns of children between 6 and 18 years in our sample with the sample size of 3,819 children. We see that the children spend around 7.6 hours, or a little more than an hour a day, studying. Boys are shown to study more at home, and work about an hour more on the farm than girls. The higher number of hours boys spend studying could be because girls spend more time working on household chores. Indeed, the data show that girls spend over a half an hour more on average working on household chores than boys. These are being collected continuously along with all the other school records.

Table 22: Balance Table: Education Outcomes for Mini-grid Sites and Non-Mini-grid Sites

	Control	Treatment	Difference in Means
Enrolled in School	0.882	0.908	-0.026
	(0.014)	(0.011)	(0.017)
Number of days in the last week that child missed school (excluding holidays)	0.239	0.305	-0.066
	(0.035)	(0.043)	(0.055)
Hours spent studying at home in the past week	7.024	8.255	-1.232***
	(0.236)	(0.345)	(0.416)
N	2530	2574	5104

Table 22 provides a difference and means between treatment and control. Standard errors are in parentheses and are clustered at the village level.

The table above displays educational indicators disaggregated by mini-grid sites and non-mini-grid sites. At baseline, children in communities with mini-grids have higher rates of school enrolment and are more likely to miss school during the week, though neither of these differences is statistically significant. Children in treatment communities study nearly one hour more than children in control communities, and this difference is statistically significant.

While there are differences in number of hours per week that children spend studying between treatment and control communities at baseline, this does bias our results. The difference in difference estimation strategy controls for initial differences in educational outcome levels and compares the *rates of change* of educational outcomes ownership in treatment vs control communities.

In addition to the indicators presented above that were collected through household survey, the research team is collecting additional indicators through administrative records stored at school facilities. The primary information we hope to obtain from administrative records is student enrolment. Moreover, we plan to work with school facilities and Ministry of Education to gain access to scores from standardized tests that are taken across the country. Trends in these indicators will be presented in end line report.

Parents and students both mentioned in Focus Group Discussions that children would be able to study later at night. During one FGD the respondents stated that during exam periods students would gather around the one solar lamp post in town to study until midnight under the light. Teachers mentioned that not having light in the daytime is not often a problem for schools, but that the lack of electricity limits the use of computers and after school activities.

3.4 Reduction of CO_2e emissions

Rural households create emissions mainly though the energy used for household lighting and cooking. Because the RREP project produces clean solar energy, RREP electrification will reduce CO2e emission to the extent that households replace existing “dirty” households cooking and lighting technologies with clean solar-electrified technologies.

3.4.1 Fuel Consumption

Households consume fuel for both cooking and lighting. Different fuel sources have different CO2e emissions impacts. In this section we describe the energy sources used for household lighting and cooking. Electricity should reduce reliance on these “dirty” fuels.

Figure 25 shows over 99 percent of households use wood/charcoal as either a primary or secondary source of cooking energy. 77 percent of households get their primary or secondary source of cooking

energy from collected firewood, while another 14 percent purchase firewood, and nearly 18 percent purchase charcoal.

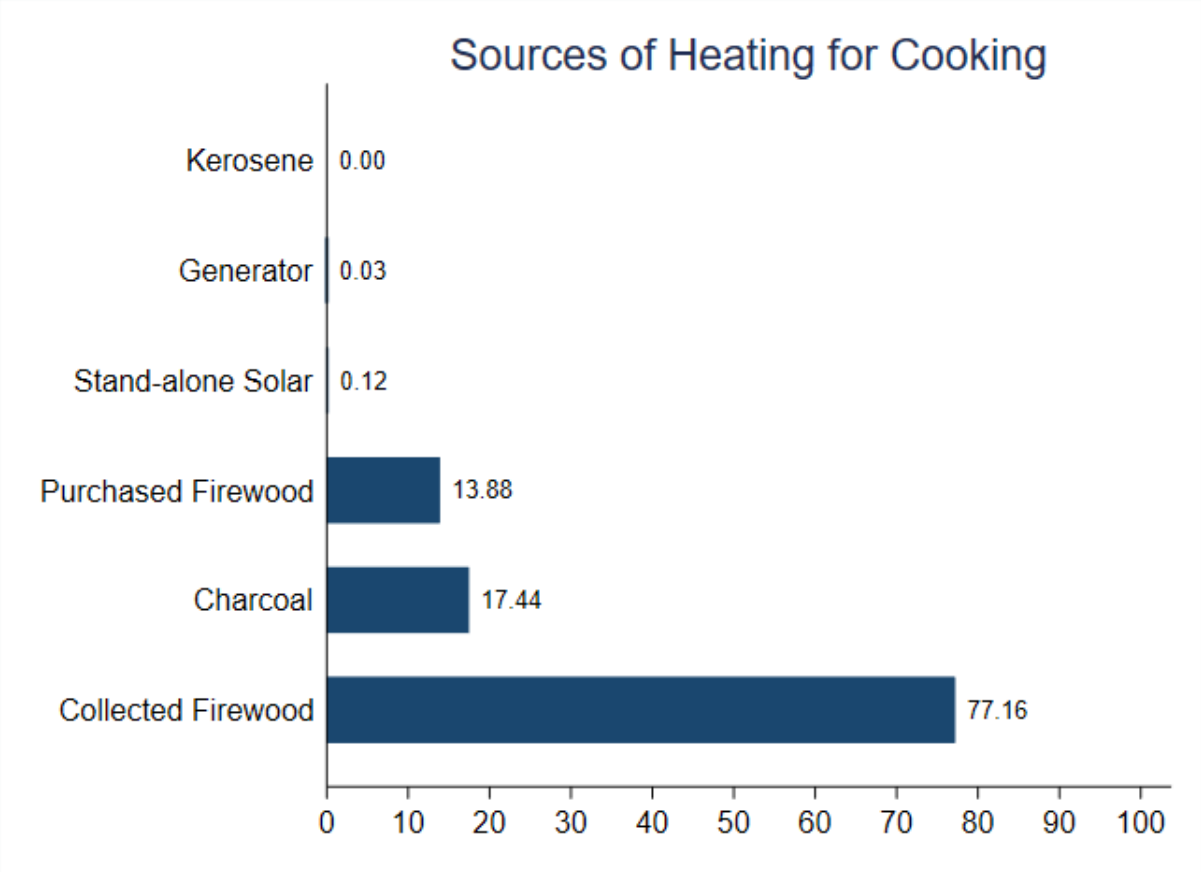

Figure 25: Source of Heating for Cooking

Figure 26 (below) describes sources of household lighting. More than half (53.45 percent) of our sample uses a battery powered lamp as their main light source, while 36.75 percent of households use solar lanterns as their primary source of lighting. All other energy sources— such as the use a generator (1.76 percent) or the use of a phone (1.14 percent – each account for less than 5 percent of households' primary source of lighting.

During Focus Group Discussions, the majority of respondents indicated that their main source of light was standard battery powered torches. The replacement cost for batteries was mentioned as a high recurring expense, on average needing to replace them every 2-3 days at the cost of 3,000 Le for two batteries. Sometimes people could not afford this and would be left without any light at home. A limited number of respondents indicated that they owned solar lanterns.

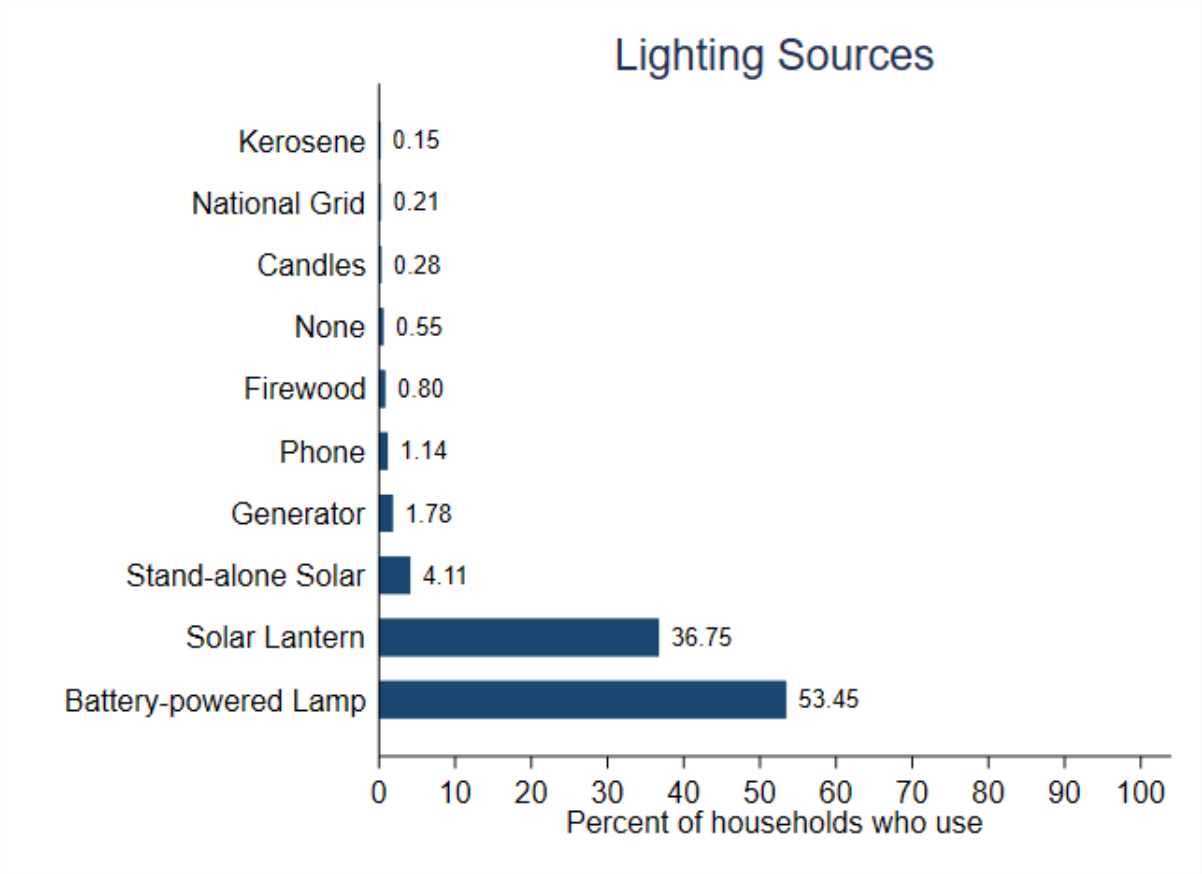

Figure 26: Sources of Energy for primary lighting

Table 23 displays differences in treatment and control communities between household energy consumption. Interesting, treatment communities are nearly 16 percentage points more likely to use solar-powered lanterns as their primary source of lighting and 21 percentage points *less* likely to use battery-powered lanterns as their primary source of electricity. In addition, while the use of cell phones as lighting is less than half a percent in control communities (.5 percent), cell phones are used for primary source of lighting in 1.8 percent of households sampled in treatment villages. These differences are statistically significant.

Table 23 - Balance Table: Sources of Household Lighting for Mini-grid Sites and Non-Mini-grid Sites

	Control	**Treatment**	**(1) vs. (2)**
Kerosene	0.002	0.001	0.002
	(0.001)	(0.001)	(0.001)
National Grid	0.000	0.004	-0.004
	(0.000)	(0.003)	(0.003)
Candles	0.001	0.004	-0.003*
	(0.001)	(0.001)	(0.002)
No Lights	0.001	0.010	-0.010
	(0.001)	(0.007)	(0.007)
Firewood	0.009	0.007	0.003
	(0.003)	(0.002)	(0.004)
Phone Light	0.004	0.018	-0.014***
	(0.002)	(0.004)	(0.004)
Generator	0.016	0.020	-0.004

	(0.004)	(0.004)	(0.006)
Solar Panels	0.028	0.054	-0.026
	(0.007)	(0.015)	(0.017)
Solar-powered Lantern	0.289	0.445	-0.157***
	(0.027)	(0.026)	(0.037)
Battery-powered Lantern	0.643	0.430	0.212***
	(0.026)	(0.026)	(0.037)
N	1601	1650	3251

3.4.2 Cooking Facility

As we saw above in Figure 25, firewood and charcoal account for nearly every households' primary and secondary source of cooking energy. This suggests that few households at baseline are using electric stoves. Table 24 shows that rates of household ownership of electric stoves hover near zero at .1 percent - .2 percent. There is no statistically significant difference between electric stove ownership in treatment and control communities.

Table 24: Balance Table: Electric Stoves

Variable	**Treatment**	**Control**	**Difference**
Stove (electric)	0.001	0.002	-0.001
	(0.001)	(0.001)	(0.001)
N	1601	1650	3251

Standard errors are in parentheses. Column 3 shows the difference in means. Stars indicate significance level.
*<.10 **<0.05 ***<0.01

Section 4: Conclusions and Recommendations

The ultimate goal of the RREP impact evaluation is to 1) provide conclusions regarding the effect of electricity on key indicators through comprehensive data collection and rigorous analysis; and to 2) provide sound policy recommendations based on those conclusions. These goals will be achieved through the methodology described in this report as well as in the inception report, and which relies on multiple rounds of data collection.

Findings presented in this report rely only on the data collected at baseline, and therefore on one (the first) round of data collection. While insightful, this only provides one piece of data necessary for the comprehensive analysis required to make conclusive recommendations. The baseline findings give us a comprehensive understanding of the economic situations in many recently electrified or soon to be electrified towns and their selected "comparison" villages. Moreover, our qualitative work gives us some insights into how local actors perceive mini-grid "ownership", which has consequences for programme sustainability.

Our first set of recommendations stem from two central baseline findings: 1) while many individuals are investing substantial amounts of time in self-employment activities, on average self-employment is not very profitable; 2) there appears to be few outside employment options.

4.1 – Recommendation 1

Policy interventions that increase the adoption of productive electrified assets should be developed and rigorously tested.

The impact evaluation will assess whether electrification increases the adoption and use of productive electrified assets/machineries. However, a substantial literature on technology adoption shows that individuals will not necessarily adopt new technologies, even when doing so would lead to welfare improvements and economic development.[20] In section 3.1.2 we detail the substantial time households

[20] Alcott, H. and J. Kessler 2018. The Welfare Effects of Nudges: A Case Study or Energy Use Social Comparisons. *American Economic Journal: Applied Economics* 11(1): 236-276

Bryan, G., S. Chowdhury and A. M. Mobarak, 2014. Under-Investment in a Profitable Technology: The Case of Seasonal Migration in Bangladesh," *Econometrica*, 82(5): 1671-1748

Cohen, J. and P. Dupas, 2010. Free Distribution or Cost Sharing: Evidence From a Randomized Malaria Experiment. *Quarterly Journal of Economics* 125(1): 1-45

Duflo E, Kremer, M, and Robinson J. (2009). Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya. *American Economic Review* 101(6): 2350-2390

Gine, X. and D. Yang, 2009. Insurance, Credit, and Technology Adoption: Field Experimental Evidence from Malawi. *Journal of Development Economics* 89: 1-11

Guiteras, R., J. Levinsohn and A. Mobarak, 2019. Demand Estimation under Strategic Complementarities. North Carolina State University, Working Paper

Meredith, J., J. Robinson, S. Walker and B. Wydick, 2013. Keeping the Doctor Away: Experimental Evidence on Investment in Preventative Health Products. *Journal of Development Economics* 105: 196-210

Meriggi N.F., Bulte, E., Mobarak, A.M., 2019. Subsidies for Technology Adoption: Experimental Evidence from Rural Cameroon, *mimeo*

invest in self-employment activities and the minimal economic returns from this time investment. In section 3.1.4, we detail the low baseline levels of electrified assets, and the minimal use of electrified assets that can be classified as "productive"— that is, used to increase economic return for a given amount of time invested.

Puzzling adoption rates (i.e. lower than optimal) have been documented for a broad range of cost-effective technologies, products and behaviours – spanning across different sectors and domains including agriculture, health and education – that, if adopted, would improve people's welfare. By better understanding which factors hamper the adoption of these technologies, products and behaviours, policy makers can take steps to remove these barriers, unleashing the full potential of electrification to drive productivity enhancement and welfare improvement.

4.2 - Recommendation 2

Policy interventions that support private sector development should be developed and rigorously tested.

In section 3.1.2 we detail the limited number of individuals employed with outside organization or firms (i.e. not self-employed). Only 8 percent of the 5,063 respondents and respondents' spouses say they have outside paid employment. It is possible that electrification will lead to private sector development that creates employment. However, for many potential businesses, the barriers to entry are more than just electrification; potential businesses face credit constraints, an inexperienced workforce, limited market connections, among other constraints. Again, it is important to properly understand those barriers to private sector development and develop appropriate interventions to complement improved access to electricity.

4.3 - Recommendation 3

The welfare benefits of policy interventions that a) support the adoption of productive technologies and b) support private sector development should be rigorously measured.

Electricity is an "enabling factor" rather than a direct "output" that necessarily leads to welfare improvements. Recommendations 1 and 2 suggest development and testing of policy interventions that complement electrification. Given that a) the RREP programme is a pioneering electrification effort in the region and b) little is known about the impact of large-scale electrification or steps that can be taken maximize the returns to electrification, the RREP programme presents an ideal opportunity for understanding how electrification can be complemented by other interventions. This can be achieved through measuring the marginal and compounded effects of these complementary interventions.

Mobarak, A.M., P. Dwivedi, R. Bailis, L. Hildemann and G. Miller, 2012. The Low Demand for New Cookstove Technologies. *Proceedings of the National Academy of Sciences*, 109(27): 10815-20.

Tarozzi, A., A. Majahan, B. Blackburn, D. Kopf, L. Krishnan and J. Yoong, 2014. Micro-Loans, Insecticide-Treated Bednets and Malaria: Evidence from a Randomized Controlled Trial in Orissa (India). *American Economic Review* 104(7): 1909-1941

World Bank, 2007. *World Bank Report 2008: Agriculture for Development*. Washington DC: The World Bank

Our recommendation is that policy interventions that attempts to increase the use of productive technologies or stimulate private sector development should be tested in conjunction with the RREP program and evaluated in coordination with the evaluation team. This coordination would allow the impact evaluation team to disentangle the effects of the electrification programme from the effects of each additional intervention and identify the additional benefits of implementing interventions together. Through effective coordination, the impact evaluation team could leverage existing data collection efforts to measure the effects of complementary interventions, thus improving cost-effectiveness of the evaluation.

4.4 - Recommendation 4

UNOPS should improve communication with stakeholders.

Qualitative research revealed that local stakeholders were often uncertain about key aspects of the RREP programme, especially concerning when electrification would come online and the maintenance of RREP infrastructure. Residents stated they did not know when to expect the electrification process to begin. Residents were well aware of when RREP installation began, stating that it has been a year since the poles have been installed but there are still no houses connected. Focus Group Discussion participants said that residents of neighbouring villages mocked them for their “furniture”, leading to concerns that the government may be “bluffing” about the electrification project.

In addition to community member concerns, several members of the District Health Management Teams mentioned that they were concerned about a lack of clarity over the maintenance of systems at the CHCs and stated that there had been limited communication on this front.

Annexes

Annexes included:

a. The original terms of reference
b. Baseline Sampling Plan
c. Enumerator Training Manual
d. Stakeholder Mapping
e. Research Permission
f. Knowledge Management Plan
g. Monetizing Education Outcomes
h. Affordability