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Rural Renewable Energy Project in Sierra Leone: Impact evaluation report

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Endline Impact Evaluation Report

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Table of Contents

1. Executive Summary

1.1 Project Background

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 USD40+ million Rural Renewable Energy Project (RREP). RREP – funded by the UK Foreign, Commonwealth & Development Office (FCDO)[1] – is an ambitious electrification project that aims to provide access to off-grid solar electricity in up to 97 communities in Sierra Leone. RREP implementation is being conducted in multiple phases; this report provides the Endline impact evaluation of Work Package 1 and Work Package 2, consisting of 97 mini-grids across 14 of Sierra Leone's 16 districts.

1.2 Methodology

This report uses data collected during the Baseline (2019) and Endline (2021) surveys, to assess the short run results of RREP's Work Package 1 (WP1) and Work Package 2 (WP2). WP1 did have another data point (Midline in 2021) that was reported previously; throughout the endline report the evaluation team will make references to the previous report but will not include those data here as it was not conducted for both work packages. To evaluate the impact of the RREP on key development outcomes, we compare a representative sample of households in RREP communities (communities where mini-grids have been installed) with a representative sample of households in statistically similar communities where no mini-grid was installed. The mini-grids in WP1 RREP communities became operational between late 2019 and early 2020, after the June 2019 Baseline data collection. Since then, in WP1 RREP villages, 65 percent of baseline respondents have been connected to the mini-grid while only 35 percent of WP2 households have been connected. We can thus also assess the impact of taking a connection. Health centres in WP1 RREP communities were electrified before the Baseline survey was conducted[2], though for WP2 not all were completed beforehand.

Comparison communities were selected using Propensity Score Matching (PSM), a statistical method used to help select similar communities. For details on this process, see the Sampling Methodology (Annex O) and Section 3.7. Prior to electrification, the RREP and comparison communities were on average similar on many key metrics of interest. However, some differences remain that were discussed in the Midline Report previously. For example, at baseline the RREP communities had higher levels on some wealth indicators, such as total livestock ownership and ownership of electrified assets. To account for such baseline differences, we use a difference-in-differences estimation strategy, comparing the changes in RREP and non-RREP communities over time, rather than looking at simple differences across these types of villages. Additionally, the RREP communities and comparison communities are on average slightly different in WP1 and WP2; therefore the analyses section will be split by work package and described in detail,

[1] Formerly the UK Department for International Development (DfID).

[2] Of the 54 health clinics in Work Package 1, 50 were electrified in 2017, and the remainder in 2018. For all clinics in our sample, we collect administrative data covering the period before and after electrification.

though may be very similar when reporting on the same variables. This estimation strategy is described in detail in Methodology Section 3.7. That section also presents example figures and tables which describe how difference-in-differences results can be interpreted.

The data collection for this Endline report was conducted between November and December 2021. Annexes B and C contain a map and timeline of the survey implementation. At that time, the Covid-19 pandemic posed an on-going risk to enumerators, respondents, and other community members. Strict precautions were taken to prevent any infection, including multiple PCR tests for all field personnel, hygiene kits distributed to enumerators, and repeated safety briefings. For a detailed accounting of Covid-19 risks and precautions, see Section 3.1 and Annexes F and J.

1.3 Main Findings

In comparing the data from the Baseline and Endline surveys, we found that households in RREP communities are in the early stages of benefitting from electrification. There have been high connection rates to the RREP mini-grids that are electrified: 65.4 percent of respondents in RREP WP1 communities were connected to the mini-grid while 35 percent of respondents in WP2 RREP communities were connected to the mini-grid, and CHCs using RREP mini-grids had varying access to electricity: Roughly 78 percent in WP1 communities received more than ten hours per day of electricity while only about 40 percent did in WP2 communities. We observe some first order effects of electrification on the transition from more traditional sources of energy to the (cleaner) electricity produced by the mini-grids and having higher access to light in Section 4.1.2 and Section 4.2.2, as well as on investments in certain electrical assets such as freezers that have really significant productive uses in Section 4.1.5 and Section 4.2.5. However, this high utilization has not yet led to large shifts in our key indicators which is to be expected in the medium-term. As detailed in Sections 4.1.3 and Section 4.2.3, we found that RREP households and comparison households were no different in 2019 except that they sowed less cocoa and harvested less cocoa, which is in line with the Midline report previously submitted. In 2021 however, RREP households nullified the effect of any difference through sowing and harvesting more cocoa in the later year. We did not find significant changes for other crops. In Section 4.1.4 and Section 4.2.4, we present evidence suggesting that households in RREP communities were not more likely to be both self-employed or wage employed than households in comparison communities. Sections 4.5 and 4.6 present our findings on assets and consumption. These results indicate that comparison communities are "catching up" with RREP communities in the number and type of assets and livestock they own, as well as in their food consumption.

Sections 5 and 6 present our findings from the school and health centre surveys, respectively. Every CHC in a WP1 RREP community has access to electricity, though in WP2 this varies on the status of the grid if it has been completed and electrified. In both work packages, the majority of schools are yet to be electrified. These sections, as well as the qualitative report in Section 7, provide evidence that electrification will greatly improve the ability of CHCs and schools to perform their functions. CHCs were much more likely to have light at night, which assuaged a common complaint among staff at un-electrified CHCs. Schools in RREP communities had higher school

attendance and many of the key informant interviews confirmed that children are coming during the evening hours to read and study if their home did not have light, which may lead to improved educational attainment and test scores for these students in the future.

The benefits of rural electrification will take time to manifest and display true impacts. However, these intermediary results from the Endline survey are promising and confirm what had been seen in the previous Midline report. We conclude in Section 8 by offering recommendations to UNOPS and other stakeholders for how best to improve the implementation of the RREP moving forward.

1.4 Results

The data summarized in this section will report first the main findings of WP1 following with WP2 for the specific subsections. WP1 was derived from a representative sample of 3,229 households across the 54 RREP and 54 comparison communities in Sierra Leone who were interviewed at Endline. Not all of the respondents surveyed during Baseline were available for the Endline: 200 households had either moved away or dissolved, and 282 households did not consent to participate in the follow up. These 2,747 households represented a 14.9 percent attrition rate from the Baseline sample. As discussed in Section 3.5, attrition was slightly higher within RREP communities: 56.2 percent of attrition occurred from communities with an RREP mini-grid. For the WP2 communities, the sample was derived from a sample of 3,790 households from the Baseline survey. Similar to WP1 communities, there were households that were not available or found for the Endline survey: 247 households had either moved away or dissolved, and 280 households did not consent to participate in the follow up. These 3,263 households represented a 13.95 percent attrition rate from the Baseline sample.

1.4.1 Energy Access and Use

As of November 2021, all WP1 RREP communities had a mini-grid installed and operational for at least 13 months. This varies by community due to the staggered electrification date of RREP communities; some sites had been electrified for longer, up to 27 months[3]. WP2 communities vary on their electrification status more than the WP1 communities, as many of them remain in the construction and installation phase.

In WP1 there were 1,354 respondents from RREP communities who were surveyed in 2021, 888 respondents (about 65.4 percent) were connected to the mini-grid in their community. WP2 had 548 connected to the mini-grid which was about a 35 percent connection rate[4]. On average, it was the more wealthy households that invested in getting connected to the mini-grid. Compared to households that are not connected to the mini-grids in the same communities, connected households were at baseline:

- More likely to have a male household head

[3] The first WP1 community to be electrified was Bumpeh Town, Bo, in July 2019. The most recent was Kukuna Town, Kambia, in October 2020. Source: UNOPS

[4] Given that less than half of the RREP communities are electrified this percentage is not discouraging

- Have relatively more adults living in the household
- More likely to be self-employed
- Own more electrical assets (e.g. freezers, mobile phones, radios, electric fans, stereo systems, televisions, etc.)
- Spend more on food and are less likely to skip meals[5].

To assess the impact of electrification, we conduct our analysis differently for the two work packages due to their electrification status. For WP1 communities we look at two levels: first, we compare respondents in RREP communities as a whole to those in comparison communities. Second, we assess the impacts for connected households in RREP communities[6]. By focusing on households which are connected to the mini-grid, these results provide more direct insight into the effects of mini-grid access. For the WP2 communities we conduct only the first stage of the analysis due to the low rate of the RREP communities being electrified.

In rural Sierra Leone, household CO_2 emissions come almost entirely from lighting and cooking. Prior to electrification (at baseline), the primary lighting sources were battery-powered lamps and solar lanterns for 90 percent of respondents, with 1.8 percent respondents reporting the use of diesel generators. Energy used for cooking was primarily through either firewood or charcoal for 99 percent of respondents prior to electrification. RREP community residents are quickly transitioning from more traditional fossil fuel energy sources to mini-grids. We find that respondents in RREP communities change energy use: households in RREP communities are more likely to have access to light and less likely to use diesel generators for lighting. The same holds when we restrict the analysis to connected households.

However, it will take time for this transition to have a substantial impact on the environment (e.g. reduced CO_2 emissions) and livelihoods (e.g. allow people to adopt more “productivity enhancing technologies”). We do not yet see a significant reduction in the use of other high-emissions energy sources, such as kerosene or firewood for both cooking and lighting. This is not surprising so soon after electrification: the energy transition to "cleaner technologies" requires time and investment in information and other marketing/financing strategies. Cleaner appliances for lighting and cooking can be expensive, and the investment necessary represents a substantial hurdle for cash-strapped households. Should appliances for cleaner lighting and cooking become more abundant/accessible and get cheaper (possibly through temporary subsidization), uptake should increase if evaluated over a longer duration of time[7].

To assess the impact of electrification, we focus on four questions within the key domains of change[8].

- How does increased access to electricity affect incomes and assets?

[5] All of these results are statistically significant.

[6] The second form of analysis, called the local average treatment effect, is discussed in more detail in the Methodology section, Section 3.7.

[7] Meriggi, Niccolò F. & Bulte, Erwin & Mobarak, Ahmed Mushfiq, 2021. "Subsidies for technology adoption: Experimental evidence from rural Cameroon," Journal of Development Economics, Elsevier, vol. 153(C)

[8] See Section 4 of Annex A for details on the domains of change.

- How does increased access to electricity affect the incidence and severity of certain health conditions?
- How does increased access to electricity affect education?
- How does increased access to electricity affect CO_2e emission?

1.4.2 Income and Assets

Agriculture is central to the rural economy and represents the majority of respondents in our sample as their main occupation. 1,370 households in WP1 grew rice which is the main staple crop in Sierra Leone and 245 reported planting and harvesting cocoa trees which is a main cash crop. 2,132 households in WP2 grew rice and 475 reported planting and harvesting cocoa trees. In Section 4.1.3 and Section 4.2.3, we analyse agricultural activity in detail.

While the majority of households farm, a substantial minority also work in non-farming self-run businesses or in formal wage employment. Summary data has previously been reported in both the Baseline and Midline reports, this report will primarily focus on the analysis of any differences over time which are presented in Section 4.1.4 and Section 4.2.4. The most common self-run businesses were petty traders. About one-third of self-run businesses required electricity to operate; the most common uses of electricity in business were for lighting, freezers, and televisions.

In the period between the Baseline and Midline surveys, we did not observe substantial changes in labor and income due to RREP. Given the short timeline and the disruptions to business activities across all communities caused by the Covid-19 pandemic, it is not surprising that few effects are observed at this early stage. This remains true in the Endline surveys as well.

Among the agricultural indicators considered for this evaluation and what we have been able to report on due to the seasonality and crop cycles, we found no differences in cocoa sowed and harvested for households in RREP villages, and households connected to the mini-grid. We also did not observe a significant difference between households in RREP and comparison communities in the amount of rice planted, harvested and sold. We also found no significant difference in non-agricultural employment trends between households in RREP communities and comparison communities[9].

It is important to note however that these results on employment and income are to be considered as intermediaries, as the time between mini-grids becoming operational and the Endline survey was in some communities limited, moreover observing effects on these outcomes takes time. Analysis of future rounds of data collection if it were possible to extend the evaluation would allow for assessments of longer-term trends in income generating activities, as more households get connected. However, investments in complements to electrification (e.g. providing increased access to credit or capital for investments in small enterprises, or incentives to health workers to work longer hours or the establishment of double shifts at CHCs to fully capitalise on the lighting at night) may be needed to induce changes in livelihoods.

[9] These results are detailed in Section 4.1.4 and Section 4.2.4

We did find some significant changes in livestock and electrified asset ownership. Households connected to RREP mini-grids saw a significant negative effect on the number of livestock owned, and found that comparison households may begin to catch up to households in RREP communities. As livestock are the main form of liquid savings in rural communities, these connected households may have sold animals to get connected to the grid and purchase electrified assets. For example, rates of ownership of productive electrical assets such as freezers were significantly higher in connected households living in RREP communities. Figures on livestock and asset ownership are presented and discussed in Section 4.1.5 for WP1 and 4.2.5 for WP2.

1.4.3 Gender Equality

Based on the Midline report and the Endline data collection, we found strong evidence of gender inequality though we do not report on this in summary statistics in this report specifically. As seen previously, fewer female-headed households in RREP communities were connected to the mini-grids than male-headed households; this is also observed in the endline results in Section 4.1.1 and 4.2.1. This may be related to differences in income and wages described in the Baseline report and Midline report.

1.4.4 Disability

As mentioned in the Midline report, there were no differences in the effects of electrification for those with disabilities. Respondents with disabilities in RREP communities were no more or less likely to be connected to the mini-grids as observed in the endline results in Section 4.1.1 and 4.2.1, nor were they significantly less likely to use cleaner energy sources in their homes and this has remained consistent from the Midline to the Endline survey. There were substantial income and asset differences between disabled and abled members of RREP communities, and these persisted from Baseline and Midline.

1.4.5 Schools

We surveyed Government and/or Government-Assisted schools in RREP and comparison communities. The schools in RREP sites have had the opportunity to connect to the mini-grid. Unlike the CHCs, the schools are expected to pay for electricity connections. As seen in the Midline report, very few schools in RREP communities had invested in connecting to the mini-grid and this has continued over to the Endline with only 14 schools in WP1 communities electrified and 55 in WP2 communities. This implies that to evaluate the full impact of electrification on educational outcomes, a longer evaluation window is needed. We did however find that RREP communities had significantly more students attending the national primary school examination, this could be a signal of improved educational attainment and test scores for these students in the future, but these may not manifest without the necessary complementarities at the school level such better resources, teacher incentives etc.

1.4.6 Community Health Clinics

The majority of community health clinics in our sample were electrified in 2017 to enable Ebola containment efforts. Since then, the RREP has electrified every CHC in the WP1 RREP communities. The electrification of Work Package 2 communities began later and was not finished at time of the Endline data collection. We surveyed CHC workers in Baseline, Midline and Endline, and collected data from the patient registers back to 2016 for WP1 communities and dating back from 2018 for WP2 communities. Around 61 percent of all CHCs in WP2 RREP communities are electrified through the RREP project. The findings from these data are detailed in Section 6.

The RREP has had substantial positive effects on electricity access in RREP CHCs, relative to comparison clinics. Among RREP CHCs, 78 percent in WP1 communities received more than ten hours per day of electricity and nearly 40 percent did in WP2 communities. Among comparison CHCs in WP1 there were 37 percent had no light at all per day, and slightly over 37 percent in WP2. By providing light throughout the day, the RREP mini-grids enabled clinics to remain open and deal with emergency patients, such as births and traumatic injuries, at night.

1.5 Recommendations

Section 8 makes five recommendations targeted at both policymakers and UNOPS for continuation of work on the RREP and future projects. The findings contained in this report combine what was found from the previous Baselines and Midline reports to emphasize the importance of assessing the impacts of electrification over the longer-term.

Recommendation 1: Rural electrification will take time for households to fully reap the benefits. Changes on farm, off farm, and further up the value chain require investment in tangent with electrification. Households lack savings to invest in multiple important appliances needed to start new economic activities. Lack of access to credit markets, poor public infrastructure, and technological familiarity all take time to catch up to improvements in energy infrastructure.

This impact evaluation of WP1 and WP2 communities conclude with the Endline survey in late 2021, though as seen in this report many changes and improvements in the RREP communities will need a longer time period to evaluate and would benefit from future data collections in the years to come.

Recommendation 2: While we observe high rates of connection to mini-grids, self-employed individuals in RREP communities are not more likely to use electricity in their business relative to self-employed individuals in comparison communities. Therefore, as mentioned in the Midline report, we recommend pursuing a deeper understanding of the barriers to the adoption of (productive) electrified assets, and design interventions that could help people in RREP communities overcome these barriers and allow a further synthesis of the evaluation.

In literature electricity is often seen as an "enabler", and therefore one should not be discouraged or skeptical about the importance of access to electricity for (economic) development[10]. Rather, now that the investment in the infrastructure has been made, it is important to focus on how to best design programmes that help people residing in RREP communities take full advantage of electricity and fully leverage on the investment in the infrastructure. For the benefit of other electrification programmes in Sierra Leone and elsewhere, it is important to rigorously test and document the impact of these programmes. These programmes though do take time to see the full impact as mentioned in Recommendation 1 and previously stated in the Midline Report.

Recommendation 3: As mentioned in the Midline Report, schools and Community Health Clinics have increased access to electricity, though it is still limited. Therefore, they now are "enabled" to operate specific devices that might increase the quality of the infrastructures. For instance, CHCs can have fridges and allow the storage of vaccines, and computers can be operated in schools to allow e-learning if this were an investment that the community pursued. In addition, both CHCs and schools could now operate longer hours. While this may improve the quality of the health and educational infrastructure, we recommend investigating complementary factors which may be necessary for reaping the benefits of electrification. For instance, one might want to think about how to install night shifts at CHCs, now that the electricity makes the lighting at night possible allowing CHCs to operate and serve patients after it gets dark. This would require coordination with relevant government counterparts to fully exploit the potential of electrification programmes.

Recommendation 4: Based on focus group discussions, people in the RREP communities find the tariff scheme and the transparency of top up for their meters rather unclear, and they find the cost of the unit of electricity too expensive. Section 7 of this Endline report discusses the qualitative report with a detailed analysis of these concerns. It is recommended to engage in an information campaign clarifying the tariff structure and how to properly confirm how much to top up with the agent on what is on their meter each day if needed. UNOPS and the mini-grid operators should take steps to reiterate the tariff and service fees with community members and listen to their complaints to see if the tariff can be reduced. While UNOPS and other stakeholders may not be able to change the price per unit of electricity, it might be worthwhile to provide incentives for the distribution and adoption of energy efficient devices, so that energy efficient devices can become more affordable to beneficiaries with the result of also making electricity units more affordable.

Recommendation 5: As UNOPS has completed the handover process of RREP mini-grids to operator companies, we recommend increasing the quantity and detail of communication with key stakeholders in these communities as some members are slightly unsure if they should try to reach out to UNOPS still or directly go to the operators. This will ensure there are no misconceptions regarding the scope and goals of the project. Similar to the Midline report, throughout the impact evaluation, we observed confusion in RREP communities about the operators responsibilities and the tariffs and fees for mini-grid use. Surrounding communities also expressed confusion and disappointment because their communities were not selected for the RREP. Communication will ease any potential future difficulties.

[10]Bryan, G., Chowdhury, S. and Mobarak, A.M. (2014), Underinvestment in a Profitable Technology: The Case of Seasonal Migration in Bangladesh. Econometrica, 82: 1671-1748. https://doi.org/10.3982/ECTA10489; Gine, Xavier. 2009. The Promise of Index Insurance. Finance & PSD Impact; No. 3. World Bank, Washington, DC.

2. Introduction

This section provides the background of the RREP project and the Endline data collection assessing the impact of the RREP programme on beneficiary communities. Sections 2.1 and 2.2 provide background to the RREP and the Sierra Leone country context. Section 2.3 discusses the Covid-19 situation and its impact on the RREP evaluation. Section 2.4 outlines the guiding principles of the impact evaluation being conducted. The Theory of Change of the RREP is presented and discussed in Section 2.5. Sections 2.6 and 2.7 present the governance structure and goals of the Endline evaluation. Data ownership is discussed in Section 2.8.

2.1 Background to the Rural Renewable Energy Project

In an effort to support the GoSL towards universal access to electricity, UNOPS is implementing the USD40+ million 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 targets large rural towns (often chiefdom headquarter towns) throughout the country that are regional focal points for economic and social life. The provision of off-grid solar electricity takes place in different phases. In Work Package 1/1+, 54 community health centres across the country were provided with electricity. In Work Package 2, 43 additional mini-grids were constructed and managed by private sector operators, all to be finalised and handed over by the end of June 2021. The handover process had been completed, though due to complications during the pandemic there have been many WP2 sites that were not electrified before this data collection was conducted. It is anticipated that Work Package 1+ and Work Package 2 will lead to more households becoming connected to electricity. A full field plan for all locations can be found in Annex C.

Three private sector operators are currently involved in operations and maintenance for the 54 existing sites, and to operate, maintain and co-invest in 43 additional, larger mini-grids the RREP. These companies were brought in through a competitive international tender. The sites have been split into four geographical lots, with Off-Grid Power awarded two; Winch Energy awarded one; and EnergiCity (a subsidiary of Ghana-based Blackstar) awarded one. Off Grid Power has since been bought by PowerGen, which also heads 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.

The remaining Work Packages include:

- Work Package 3, focuses on improving the enabling environment to support private sector investment, and commercial sustainability of off-grid electricity provision through providing technical capacity building support 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 closely coordinating with the impact evaluation team.
- Work Package 6 focuses on providing productive use assets targeted to entrepreneurs through assistance with an implementation partner.

- Work Package 7 provides support through tariff subsidy for Tariff Affordability for non-generation assets and elimination of public reserve account payments. Through this work package, additional funds will be used to procure non-generation assets (electricity meters and indoor connection materials, e.g. sockets), and to eliminate public reserve account payments by the operators for the first four years of the project. UNOPS will act at the directive of FCDO and manage the Fund, disbursing only at agreed times to procure indoor connection materials in-house (for economies of scale) and transferring into the Reserve Account (for the Operators' procuring their meters, which are proprietary, and for predictive maintenance) as per the PPP agreement.

The expected impact of the project is that it will improve Sierra Leone's economic development through an increase in access to rural renewable 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 CO_2 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 intended outcome of the project is to improve rural renewable energy access through private sector involvement. It is estimated that approximately 346,015 direct and unique beneficiaries in rural Sierra Leone will be connected to electricity. The definition of 'Direct and Unique Beneficiaries' includes to count the beneficiaries once in order to avoid double counting (e.g. a household beneficiary may also be a CHC beneficiary). These beneficiaries will access connections through households, reaching 166,944 people; CHCs, reaching 114,666 people; schools, reaching 27,253 teachers and children; commercial and productive uses reaching 11,106 people; and the WP6 grants programme reaching 26,046 people.

Direct Beneficiaries		
Beneficiary Type	# of Connections	Direct & Unique Beneficiaries
School	130 schools	27,253
Households	24,126 households	166,944
CHC	97 CHC	114,666
Commercial/ Productive Users	2,171	11,106
Matchings Grant (WP6)		26,046
Total Direct Beneficiaries		**346,015**

The project also has indirect beneficiaries. This number is calculated as the remaining number of people in the catchment areas who are expected to benefit from the increase in services, improvement in service delivery, and increased income. These numbers are estimated as follows:

Indirect Beneficiaries	
Estimated Catchment Population (94 sites)	719,991
Direct Beneficiaries	346,015
Total Indirect Beneficiaries	**373,976**

This report is part of an impact evaluation of the RREP programme from the baseline in 2019 to endline in 2021. The impact evaluation was initially designed to focus on the effect of increased access to electricity through the implementation of Work Packages 1/1+ and 2. However, the evaluation team seeks to extend the scope of work to evaluate Work Package 6 in the coming year.

Following the installation of RREP mini-grids, a number of additional Work Packages will support work on non-generation infrastructure, private investment, and additional monitoring and evaluation, in particular Work Package 6. Work Package 6 will be providing productive-use assets targeted to entrepreneurs with the assistance of the implementation partner Easy Solar.

The evaluation of WP 1/1+ and 2 in combination with WP6 enables UNOPS, FCDO, and other stakeholders to assess the returns from private sector development alongside an electrification project. There is currently limited understanding of the benefits of private sector development in productive use assets alongside rural electrification projects. An expanded evaluation of Work Package 6 will offer the opportunity to separate and measure the effects of a) increased access to electricity, and b) increased access to electricity and returns from productive use of electricity.

The evaluation team intends to test if the development benefits of electricity are greater when rural entrepreneurs have increased access to productivity enhancing technologies that require electricity. Electricity is an enabling technology; the impact of electrification is conditional on the use of other productive technologies. To realize the productive potential of expanded access to electricity, access to these technologies is necessary. Although such an extension would not require substantial modifications to the data collection plan for the impact evaluation team,it would require modifications in the implementation of WP6 activities and the randomization of some activities. Unfortunately, despite some attempts at coordinating this extension, the opportunity has not materialized yet.

2.2 Country Context

Sierra Leone is one of the world's poorest countries, ranking 182th out of 189 countries in the Human Development Index in 2020[11]. Poverty is widespread with more than 53 percent of the population living below the national poverty line[12]. 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 schools[13].

There is a critical shortage of skilled health personnel 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[14].

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[15]. 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[16].

In Sierra Leone, only 2.5 percent of the population in rural areas have access to electricity[17]. Poor access to electricity is recognised as a binding constraint to long-term economic growth in Sierra Leone[18]. 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. By 2023 the Government plans to:

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

[11] UNDP http://hdr.undp.org/en/content/latest-human-development-index-ranking

[12] World Bank http://databank.worldbank.org/data/views/reports/reportwidget.aspx?Report_Name=CountryProfile&Id=b450fd57&tbar=y&dd=y&inf=n&zm=n&country=SLE

[13] The New Direction

[14] UNICEF Situational Analysis 2019

[15] UNDP http://hdr.undp.org/en/content/income-gini-coefficient

[16] UNICEF Situational Analysis 2019

[17] World Bank SE4ALL

[18] Rural Renewable Energy Project Brief, UNOPS 2018

- Increase investment in low-cost renewable energy (solar, hydro, wind, and biomass) production and distribution.
- 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.
- Ensure expansion of the transmission grid nationwide by increasing the annual regular kilometric coverage.
- Ensure rural electrification is carried out through engagement and involvement of key stakeholders, including the private sector.

The GoSL approved in 2019 the Electricity and 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.

2.3 Covid-19 in Sierra Leone

The first case of Covid-19 was reported in Sierra Leone on 31 March 2020. Since then, there have been a total of almost 4,100 cases of Covid-19 in the country as of early May, with 79 reported deaths. The first public notice from the Government was on 19 March 2020 when the country announced that all commercial flights would be suspended effective 21 March 2020, until further notice. This was lifted on 22 July 2020, four months later.

As cases rose, the Government enforced two three-day curfews from 5 April through midnight on 7 April 2020, and from 3 May through midnight 5 May 2020. Shortly following the first lockdown, on 9 April the Government enforced an initial two-week curfew and inter-district travel ban for 76 days until June 24.

On 24 June the inter-district travel ban was lifted after 79 days, but other safety measures on social distancing and a nationwide curfew from 10pm to 7am throughout the country were put into place subject to review. When the airport reopened on 22 July, precautionary steps were taken from the government to enforce contact tracing on every individual coming into Sierra Leone.

The Government shifted curfew timings in the country and the curfew was eventually fully lifted on 26 October for a trial period of four weeks. After these four weeks, the Government announced that the curfew from 11pm to 5am would continue until otherwise advised and has remained in place throughout the new year in 2021. On 25 January, 2021 the Government placed restrictions for an initial two weeks on travel in and out from Western Area with mandatory Covid-19 testing. This restriction on travel was lifted once the two weeks finished and the country has not had severe Covid-19 restrictions since.

2.4 Impact Evaluation of the RREP

This report provides results of the Endline survey which forms part of the RREP Impact Evaluation. The purpose of the impact evaluation is to understand how information and knowledge gained can help shape the policies in the energy sector and improve collaborations with other organizations outlined above that are seeking opportunities to expand in Sierra Leone. It will also enable stakeholders to quantify impacts and expand such interventions into other communities within Sierra Leone.

The Endline survey aims 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 RREP mini-grids were installed with households in similar communities where no mini-grids have been installed. 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. Section 3.7 describes how the difference-in-differences methodology measures causal effects of the RREP between beneficiary and non-beneficiary units at Baseline and Endline. These effects will be measured in two separate analyses: WP1 first and then WP2. The work packages will be analysed separately due to the types of communities that reside in each:

- WP1 communities were on average smaller communities than WP2
- WP 1 communities were electrified years before WP2
- WP2 communities have not been fully electrified[19]

The Impact Evaluation will enable RREP stakeholders to:

- Build the evidence base for further off-grid rural electrification projects across the African continent and beyond

[19] According to the operators, more than half of the WP2 RREP sites have not been electrified

- Build the evidence base for a model for public-private partnership in rural renewable energy provision
- Report to beneficiaries, stakeholders and donors on what has been achieved through the project life.

The primary objective of the Impact Evaluations is to understand: What is the impact of mini-grids as part of RREP? To understand the impact, we will look at the following four “Impact Domains”:

- Does increased access to electricity increase incomes and assets?
- Does increased access to electricity improve health conditions?
- Does increased access to electricity increase school attendance?
- Does increased access to electricity reduce CO_2e emission?

These are the changes that will be monetized by the Impact Evaluation Team led by WUR at the Endline following the methodology described into detail in section 3.7 of this report. Once the Endline survey is completed, the impact evaluation team will be able to measure improvements imputable to RREP and make monetary conversion. As described into detail in section 2.5, monetization will rely on strong assumptions.

The impact evaluation will investigate the effects of RREP on across gender, 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.

Timeline of Key Activities	
Key Evaluation Activity	Key Timelines
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
Baseline WP2	
Deliver Inception Report	September 2020
Data Collection	November - December 2019

Deliver Baseline Report	February 2020
Midline WP1/1+	
Deliver Inception Report	January - March 2021
Data Collection	March - April 2021
Deliver Midline Report	May 2021
Endline WP1/1+/2	
Deliver Inception Report	November 2021
Data Collection	November - December 2021
Deliver Endline Report	January 2022

2.4.1 Impact of Covid-19 on Timelines

As a result of Covid-19, the Endline assessment was conducted in the final quarter of 2021. Due to the high degree of uncertainty of when it would be safe to continue data collection in person, the Impact Evaluation team at WUR agreed with the UNOPS team and agreed to regularly reassess when to resume operations. This allowed for all communities of WP1 and WP2 to be electrified and included in the measurement of impact at Endline.

After considering all Covid-19 related risks posed to the enumerators and to the people residing in the project communities, and seeing a substantial reduction in cases, the team decided in November 2021 that the enumerators should be deployed to the field for data collection. A very cautious approach with strict safety protocols was implemented to ensure the safety of all involved. These details are included below, and in Annexes G, and J.

2.4.2 Guiding Principles

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[20]. 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.

RELEVANCE: IS THE INTERVENTION DOING THE RIGHT THINGS?

The project has an approved result framework which is the basis of managing, comparing and capturing the desired results (at the output, outcome and impact levels) of the project. As adopted in the methodology of the impact evaluation, it intends to assess/calculate the achievements of the project impacts. The impact evaluation study, through the Baseline, Midline and Endline

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

surveys, will assess whether the desired changes/outcomes are realized and serving the purpose of the target groups i.e. whether the interventions carried out targeting each result is relevant and acted rightly or deflected from the targets.

COHERENCE: HOW WELL DOES THE INTERVENTION FIT?

The evaluation strategy includes the collection of data both from the RREP communities (i.e. people those are benefited by the project interventions) and comparison communities (i.e. people those are not covered through the project interventions). Survey data is collected separately for WP1/1+ sites and WP2 sites. All the comparisons, comparison vs mini-grid and WP1/1+ and WP2, made on the basis of these four types of datasets will provide an option to see how the planned project interventions in the target sites and groups fit to ensure the optimum results for the target groups.

EFFECTIVENESS: IS THE INTERVENTION ACHIEVING ITS OBJECTIVES?

Again, the effectiveness criteria is explicitly addressed through the 'difference–in-difference' model of the evaluation. This model will provide an opportunity to analyse the extent to which the project interventions achieved its objectives across the different beneficiary groups of the project.

EFFICIENCY: HOW WELL ARE RESOURCES BEING USED?

Through the impact evaluation, all the resources utilized for ensuring the results of the project will be assessed to justify the rationales e.g. whenever we collect survey datasets from the CHCs, schools, businesses and households, it will be triangulated with the information related to resources (for an example-financial information and timeline) in order to see how the project ensured the best utilization of resources (competitiveness of prices etc.) to ensure the objectives.

IMPACT: WHAT DIFFERENCE DOES THE INTERVENTION MAKE?

The achievements of the project impact indicators will be calculated through this impact evaluation study which is the core objective. It includes assessing the impacts of the project in terms of changes in the household income, improved health and education, reduced CO_2e etc. The changes will be determined by comparing the results between mini-grid and comparison sites and WP1/1+ and WP2 sites (though this report will only be assessing the WP1/1+ sites).

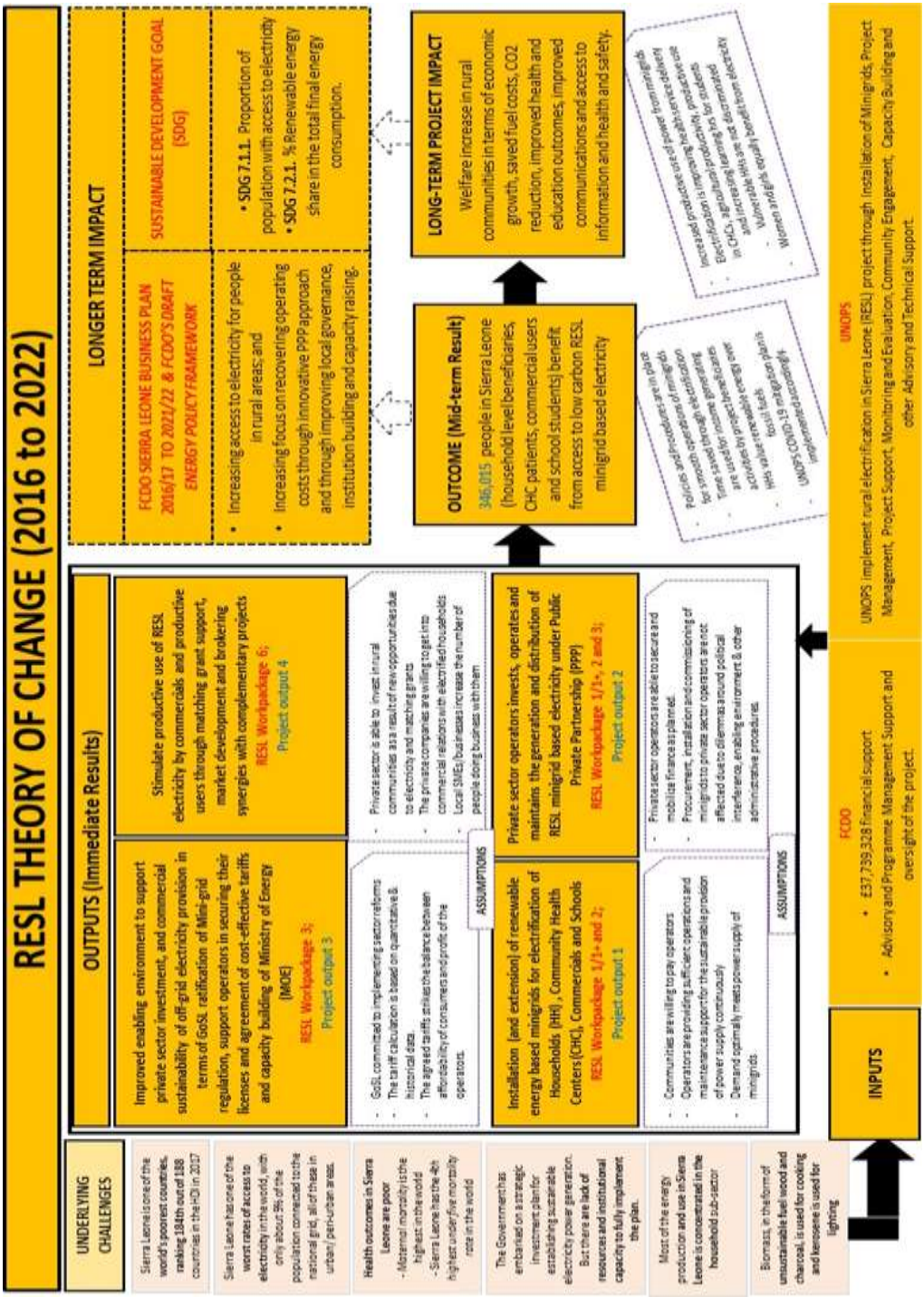
SUSTAINABILITY: WILL THE BENEFITS LAST?

The project has an already set up economic model which assumes the discounted benefits (monetisable values) of the project within the life of the project and after 13 years of implementation. The evaluation strategy contains methodology to determine the benefits of the project through the life of the project which will serve as the basis to calculate the mid-term and longer-term benefits of the project as well.

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.

2.5 RREP Theory of Change

The Theory of Change (ToC) of the mini-grids created under RREP, below, describes the mechanisms through which access to electricity is expected to impact the desired outcomes. The ToC describes how the inputs of the project are expected to lead to improved outcomes and, ultimately, positively impact the targeted population.



The 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.

We provide details on the RREP outputs, outcomes, and assumptions in the following sections.

2.5.1 Outputs

- Electrification of Community Health Centres (CHC) and extension of the mini-grids to households communities (WP1 and WP2). This provides access to reliable electricity to rural areas that otherwise are unpowered.
- 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.
- Improved environment to support private sector investment, and commercial sustainability of off-grid electricity provision.
- Increased demand for electricity provided through stimulation of private sector development. This sparks interest for private firms to explore business opportunities in rural areas.

2.5.2 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*."

2.5.3 Assumptions

The impact assessment team will continually reassess the underlying assumptions of the ToC. For example, the ToC assumes that the following will take place over the course of the project:

Output Level Assumptions

- Private sector operators are able to secure and mobilize finance as planned.
- Procurement, installation of mini-grids and commissioning to private sector operators is not affected significantly above the tolerance level due to dilemmas.
- Communities are willing to pay operators.

- Operators are providing sufficient operations and maintenance.
- Demand optimally meets power supply of mini-grids.
- Communities have strong relationships with operators.
- The targeted businesses are able to co-invest.
- Conditions specified in productive use strategy and call for proposals are met.
- The private companies are willing to get into commercial relations with people in the mini-grid catchment areas.
- Local SMEs/businesses increase the number of people doing business with them in their communities.

Outcome Level Assumptions

- Increased productive use of power from mini-grids.
- Electrification is improving the health service delivery in CHCs and increasing learning hours for school going children.
- Vulnerable HHs are not discriminated against.
- Women and girls equally benefit from electricity.
- UNOPS Covid-19 mitigation plan is implemented accordingly.

Impact Level Assumptions

- Policies and Procedures are in place for smooth operations of mini-grids.
- Time saved through electrification will be used for income generating activities by women and men.
- Electrical appliances yield better results.
- Students use their extra time available to study.
- HHs value renewable energy over fossil fuels.

Understanding whether these assumptions are correct and where they might fail will be critical to assessing the impact of the RREP.

2.5.4 Key Stakeholders

The key stakeholders and end users of this report include the Government of Sierra Leone, in particular the Ministry of Energy (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.)

2.6 Governance of Endline

UNOPS coordinates the design and management of the study for the impact evaluation of the RREP. The Impact Evaluation Team led by Wageningen University and Research (WUR) and its partners, including Yale University and the International Growth Centre (IGC) was selected by UNOPS for the implementation of the RREP impact Evaluation.

Qualifications of the Impact Evaluation team lead by WUR are Annexed to this document (see Annex E for competencies of key personnel).

Overview of Endline Governance	
Partner Name	Roles and Responsibilities
Wageningen University and Research	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 Coordi- nator, the Research Associate, the Qualitative Researcher, Field Manager, Field Coordinator, and Enumerators. ● Development and finalization of data collection tools ● 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 im- plementation. It will also lead to data analysis and cleaning. Yale University contributions are overseen by the Team Leader, Mushfiq Mobarak. ● Development and finalization of data collection tools ● Evaluation design ● Training of enumerators ● Analysis of all Baseline, Midline, and Endline data ● Support with reporting ● Data cleaning ● Development of infographics

International Growth Centre	IGC is responsible for providing the Research Manager to over- see research design. The Research Manager, Niccolo Meriggi, will be based full-time in Sierra Leone. ● 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, FCDO, Inen- sus), and between Key Personnel and field teams.

Though many of the duties overlap across the three main actors of this project, the more specific responsibilities are outlined in the table on the previous page. Each partner's tasks are fitted to their expertise, and regular reporting and communication between the partners enables sharing these expertises. The project team will also be updating the UNOPS throughout the main phases of the project.

UNOPS together with the Impact Evaluation team engaged the M&E department of the MoE in Sierra Leone as one of the key stakeholders to coordinate the design and implementation of the Baseline study for the RREP. The MoE assists with reporting and provides more detailed insight on the use of mini-grids and the implications for future complementary policies. UNOPS will work closely with FCDO during the entire evaluation process and will be updated when milestones have been completed. Feedback from UNOPS is taken with the utmost consideration to allow a diversification of perspective within the project to ensure no bias from the reporting team. Throughout the Impact Evaluation process to date the Government has been engaged and its recommendations are included in the evaluation approach. The Project Board is regularly updated on all the activities under the M&E workstream of the project.

RREP and the Impact Evaluation team have no potential conflicts of interest with any of the acting partners. If a conflict of interest does arise, it will be reported and discussed with UNOPS about how it would affect the quality of the data and overall sustainability of the project. The partner who shows to be the conflict of interest would be removed from the Impact Evaluation team in discussion with the Project Board.

2.7 Purpose of Endline

The purpose of the Impact Evaluation is to estimate the effects of the mini-grids on community welfare and development. As mentioned in section 1.4, the Endline data collection will measure the target population's current socio-economic status across the four key domains of change, and will be compared with the Baseline data that was collected more than 2 years ago. The four domains of change are:

- Household Income and Assets
- Improved Health
- Education
- CO_2 Reduction

Research Questions and Structure	
Key Research Questions	Report Section Addressing Questions
1. Does increased access to electricity increase incomes and assets?	
• Agricultural production • Non-agricultural activities • Livestock and land ownership • Household assets ownership	Sections 4.1.2, 4.2.2, 4.1.3, 4.2.3, 4.1.4, 4.2.4, 4.1.5 and 4.2.5
2. Does increased access to electricity reduce incidence of these health conditions?	
• Acute respiratory infection (ARI) • Cataracts and itchy eye • Other disabilities • Other disease prevalence • Neonatal and under-five mortality • Maternal death	Section 6
3. Does increased access to electricity increase school attendance?	
• Higher student attendance • Improved literacy	Section 5
4. Does increased access to electricity reduce CO_2e emissions	
• Household fossil fuel consumption	Section 4.1.2 and 4.2.2

The Endline data will be compared against the Baseline survey data to assess the dynamics of the medium-term impacts of the RREP's mini-grids. For a detailed overview of the methodology see Section 3. The Impact Evaluation Team will be learning from the data collection process if there are modifications needed and will adapt accordingly while updating the appropriate partners in RREP.

In WP1, 54 stand-alone solar photovoltaic (sPV) systems were constructed between September 2017 and February 2018 providing electricity access to the clinic and school. Access to electricity was made available to households in July 2019. The Endline survey can assess the short run (two years and 3 months) impacts of RREP in WP1 sites. In WP2, 42 stand-alone systems were constructed, though 24 of them were not electrified when the Endline survey was conducted.

Annex C contains the field plan for the Endline survey, presenting the list of both RREP beneficiary communities (Treatment) and comparison communities not benefiting from RREP directly (Control). It is worth mentioning that the field plan presented in Annex C was based on the Government's current Covid-19 restrictions and UNOPS' and WUR's risk analysis and had been subject to changes upon approval from UNOPS. Any changes were discussed with and communicated to the UNOPS team.

Findings will be disseminated to stakeholders for insight into what short run changes have taken place in communities as a result of the RREP. Both of these areas will serve to provide further insights for policy makers. (See Annex K: Knowledge Management Plan for further details.)

2.8 Data Ownership

UNOPS has access to all intellectual property, products, processes and documents that are developed for the Endline report and the Impact Evaluation. UNOPS has a perpetual license to use this intellectual property as it sees fit once all parties have agreed[21].

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

3. Methodology

This section provides an overview of the methodology and data sources developed and used by the impact evaluation team led by WUR during the Midline assessment. Section 3.1 details the impact of Covid-19 on the Endline. The first subsection 3.1.1 describes the training mechanisms that were taken. Section 3.1.2 explains the field work through the new Covid-19 additions. Section 3.2 describes the approach to delivering the field work. Section 3.3 provides an overview of data cleaning processes. Section 3.4 explains the different streams of evidence employed to feed into the analysis. Section 3.4.1 explains the approach to measuring the impact of the thematic impact domains. Section 3.4.2 briefly covers the analytical approach used to report on Endline findings. We present details on how the Endline results are reported in Section 3.5. Section 3.6 discusses steps taken to promote inclusion and ethics. Finally, Section 3.7 presents the difference-in-differences methodology used to evaluate and present results.

3.1 Impact of Covid on the Endline

The evaluation team reviewed the methodology and approach in light of COVID-19. While the approach and processes related to data collection will be adapted, the overarching methodology will remain constant. The team will be employing a Difference-in-Difference estimation strategy for the assessment of the impact of RREP. (Please see Theory of Change Figure 1.)

The research plan timeline has changed as indicated above. The research processes, both training and field work, were also adapted to ensure better social distancing, hand-washing, and COVID-19 risk mitigation.

3.1.1 Training

The team selected a training venue large enough for the 80+ enumerators, supervisors, and coordinators to socially distance. The seating arrangements inside the training venue were sufficient for all participants to be seated at least 2 meters distance apart. All attendees were provided with three reusable cloth masks; mandatory masking was enforced throughout the training period. Outside of the entrance of the training venue, a veronica bucket filled with a water and disinfectant mixture was placed and maintained to enable all participants to wash their hands throughout the day. At the beginning of the training, a COVID-19 safety training was provided, based on an informational sheet on COVID-19 from WHO (Annex J). In addition, the team provided fliers provided by UNOPS on how to make safer choices and how to wear a mask properly. At the end of the training, the enumerators selected for field work were tested for COVID-19 to ensure everyone is negative before leaving Freetown. All tests returned negative.

3.1.2 Field Work

The research team provided more substantial transport and daily subsistence allowances to the enumerators, in order to mitigate the number of people the field team will be interacting with. Prior to fieldwork beginning, the enumerators were given additional reusable cloth masks, hand

sanitizer and Dettol to be taken to the field with them. They were instructed to maintain social distance from all participants and conduct any in person interviews outside.

3.2 Approach to Delivering Fieldwork

In addition to the field work undertaken with the relevant Covid-19 precautions, 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 relied upon several secondary data sources both in an effort to construct a representative comparison 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 comparison 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 the 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. KIIs 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 opinions are very much needed to adequately evaluate the impact of the intervention.

Focus Group Discussions (FGD)

FGDs were conducted in communities 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.

3.3 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 2.6: Inclusion and Ethics.

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 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 to track the changes that other team members have made. In addition, the cleaned files were periodically 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 were made, and each analyst reviewed those changes after each version. In addition, every cleaning code produces a log file which results in a full report that is printed at the end of the code. Log files were saved in their own repository and ensured 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 could easily be communicated to the PIs for feedback, troubleshooting and high-level decisions.

3.4 Approach to Measuring Endline

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.

3.4.1 Measuring Thematic Impact Domains

This Endline 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_2 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 long term stages; and to understand the equity considerations of the electrification of rural communities.

3.4.2 Description of Key Indicators

For each outcome domain, this report will first describe how the Key Indicators relate the high-level outcome domain indicators. Then it will describe the specific survey measures that are used to construct these Key Indicators. While describing how the key Indicators relate to the outcome domain, this will review why electrification might change Key Indicators - therefore reviewing the assumptions in the theory of change.

Domain 1: Household Income and Assets

Relation of Key Indicators to Outcome Domain

Electrification can impact income activities and asset accumulation in both agricultural and non-agricultural sectors. Only by measuring both can we obtain accurate assessment 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 farms 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 products 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 is 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 measured at Baseline and once again at Endline ownership of electrified assets, so that we may gauge how electrification affects the adoption of electrified assets over time.

Domain 2: Improved Health

Relation of Key Indicators to Outcome Domain

Electricity has the potential to drastically improve health outcomes. This report will lay out the measurements of 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 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 with universal basic functions and identifying a portion of the 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 CO_2e emissions. Each household member is asked if they have difficulty seeing, 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: Neonatal Mortality
Within the survey we ask if there is a woman in the household who has given birth in the last year to filter according to whether we will ask further questions about the pregnancy. 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.

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.

Domain 4: CO_2 Emissions

Relation of Key Indicators to Outcome Domain
Rural households create emissions mainly through 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 CO_2 emissions. Electricity should reduce reliance on these "dirty" fuels.

Key Indicator B: Cooking Facility
Home cooking is a leading area 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.

3.5 Approach to Reporting Midline Findings

3.5.1 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 and 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, enumerators and respondents 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 the 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 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 mini-grid and comparison communities respond to questions in a different way. There is no reason to expect

that we will have more measurement error in mini-grid compared to comparison 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 regions, 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 mini-grid and comparison and therefore create no bias.

3.5.2 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 else's 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 households from this list. (See Annex O 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 mini-grid and comparison communities. We can test for this pattern by regressing RREP status on non-response in a given variable. If there are differences across these groups, we can analyse which kinds of people are not responding so that we can better interpret our findings.

3.5.3 Attrition

Not all households which were surveyed in the Baseline round were available for the Endline survey in both WP1 and WP2. Attrition could pose a threat to our identification strategy if we observed differential attrition by mini-grid status. We find that households in RREP communities are less likely to be unavailable for the survey; these results are presented by the work package in the following subsections. This could bias the results, leading us to overestimate or underestimate the effect of electrification. However, this non-random attrition can bias our results, and we correct for this using inverse probability weighting[22].

[22] Inverse Probability Weighting is a technique of re-weighting the sample to account for biases emerging from non-response from specific sub samples. It involves generating sampling weights for each respondent, as a function of variables that predict response. And then assigning these weights to each regression estimation. It will hence up-weight those respondents that are more likely to drop out in the Endline Survey

3.5.3.1 WP1 Attrition

Of the 3,229 households surveyed in Jun 2019, 482 people were unavailable for the Endline in 2021. Of these, 94 households lived in comparison communities and 106 lived in mini-grid communities who were unable to be located. Attrition had multiple causes: some households had entirely moved away from the community to go to larger communities in order to treat illnesses, and many households were not able to be found by the entire community thus noted as “untraceable”. Other households had “dissolved" through a marriage with another household. From the households surveyed at Endline, an additional 282 respondents did not consent to be surveyed again; 95 from comparison communities and 187 from RREP communities. Accounting for attrition and non consent we reach a sample of 2,747 from a sample of 3,229 at Baseline for an attrition rate of 14.9 percent. This provides an 85.1 percent response rate.

Table 1: WP1 Endline Attrition

	(1) Attrited	(2) Not Located	(3) Non consent
RREP	-0.0500**	-0.0516**	0.0583***
	(0.0239)	(0.0239)	(0.0180)
N	3229	3229	3029
N Clusters	108	108	108
Control Mean	0.174	0.171	0.064
Proportion Reached	0.851	0.854	0.907

Regression with district FE, clustered SE in parentheses

3.5.3.2 WP2 Attrition

Of the 3,790 households surveyed in November and December 2019, 527 people were unavailable in 2021. Of these, 106 households lived in comparison communities and 141 lived in mini-grid communities that were not able to be found. Attrition had different causes in the WP2 communities: some households had entirely moved away from the community they lived in during the Baseline due to family reasons of marriage or severe illnesses, while some households passed away and others were not able to be located in the community at all. From the households surveyed at Endline, an additional 280 respondents did not consent to be surveyed again; 121 from comparison communities and 159 from RREP communities. Households had become more reluctant to participate due to the status of the RREP mini-grids. Accounting for attrition and non consent we reached a sample of 3,263 from a sample of 3,790 at Baseline for an attrition rate of 13.9 percent. This provides an 86.1 percent response rate.

Table 2: WP2 Endline Attrition

	(1) Attrited	(2) Not Located	(3) Non consent
RREP	-0.0868***	-0.0902***	0.0201
	(0.0235)	(0.0234)	(0.0150)
N	3790	3790	3543
N Clusters	86	86	86
Control Mean	0.181	0.180	0.069
Proportion Reached	0.861	0.863	0.921

Regression with district FE, clustered SE in parentheses

3.6 Inclusion and Ethics

A detailed inclusion and ethics approach is applied to the impact evaluation, taking into account FCDO's commitment to human rights-based approaches of participation and inclusion, non-discrimination, equality, and accountability. WUR staff have been working in Sierra Leone for 16 years, and have 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 concerns 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). This approval is included in Annex M.

3.6.1 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 SurveyCTO software on smartphones/tablets and was sent to the server through 3G. Other than usage analytics and crash reports SurveyCTO software does not send or communicate any survey data information back to SurveyCTO 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).

3.6.2 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. The exact wording of the informed consent is included Annex Q. The training instructions for the informed consent are included in Annex H. During training, each enumerator was tested on the informed consent multiple times by WUR staff. Enumerators also passed a test which asked about standards for consent and non-consent. As discussed in Section 3.5.3, 562 respondents did not consent to participate. In all cases, the survey was immediately terminated.

In addition to consent, 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.

3.6.3 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 household questionnaire covers sensitive topics, including sections on household income, health, time use, and spousal decision-making. Substantial efforts are made to ensure that respondents only answer questions they are comfortable answering and that they understand they have the right to refuse to answer any question in the survey. Enumerators are trained to emphasize this right throughout the survey, and to administer the survey with non-aggressive body language. For details on enumerator training, please see Annexes G, H, I and P.

Additionally, the survey instrument was designed to take as little time as possible from the respondent during interviews so as to not be a burden on the respondent. Many respondents participate in the survey while working on their farm or in their business; enumerators are trained to be as non-disruptive to the respondents as possible. The team also recruited field staff who as

far as possible spoke the appropriate local language to ensure that the respondents felt comfortable.

3.6.4 Withdrawal from Study

All study participants have the right to withdraw from the study at any point. Respondents are regularly informed of this right, and are free to terminate a survey at any point while being reassured that they will receive absolutely no negative effects from withdrawing from the study. 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.

3.7 Difference-in-Differences Estimation

Difference-in-differences (DID) is a statistical technique which simulates an experimental design to determine the differential effect of an event on one group by comparing it to a similar group which was not affected. In this report, we refer to the "RREP" or "mini-grid" group of communities, in which mini-grids were installed and became operational, and "comparison" communities, which will not receive UNOPS mini-grids but were chosen because of their similarity to the RREP communities[23].

In the Baseline survey, we examined both groups prior to the commissioning of the RREP mini-grids. We assume that key differences between the two groups will follow *parallel trends*. This assumption implies that, absent the RREP mini-grids, we expect that the change in, for example, fuel consumption between the Baseline and Endline surveys will be the same in both RREP and comparison communities. Any observed difference over time can be attributed to the mini-grids provided to RREP communities.

Throughout the following sections of this report, we will provide difference-in-differences results in the form of regression tables. Each of the difference-in-difference tables will be presented in the same manner as the example below in Table 3, using faux data in the same example that we provided during the Midline report for WP1 communities. Column 1 reports the sample size that is captured in the regression estimation. Here, for each agricultural item for sowed, harvested and planted the same sample size was given of 1,000 respondents. Column 2 presents the unconditional mean in the comparison communities in 2019, while column 3 presents the difference between RREP and comparison households in 2019 conditional on districts and other effects on the mean, with standard errors in parentheses underneath the coefficient. The sign on the coefficient and significance levels in column 3 will be telling of what Baseline differences there were between the RREP communities (column 3) and comparison communities (column 2). Column 4 reports the coefficient of the year variable of Midline indicative of the time period after

[23] The evaluation team used census data provided by Statistics Sierra Leone in the algorithm that helped match RREP and comparison communities. The dataset used for this algorithm used demographic variables, population size, structure quantity and type, and household-level asset variables. See Annex O for details on the matching procedure

electrification, it is the change from 2019 to 2020 for both RREP and comparison households, and then column 5 reports the interaction of the year change (2019-2020) and mini-grid status (being electrified or not). The coefficient in column 5 is what will be determining if electrification is making an impact over time between the RREP and comparison communities. This sign on the coefficient is important because it will show if the impact is more or less in the RREP communities. If the sign is negative, that might mean that electrification is not having a positive effect on the RREP communities, or it could be the case that comparison communities are actually catching up to the RREP communities for the variable of interest. If the sign is positive this might mean that the electricity is positively affecting the mini-grid communities at the percentage the coefficient reports. The stars next to the coefficients denote statistical significance. Statistical significance relating to this estimation (in column 5) means that electrification is making some sort of impact on the RREP communities compared to the comparison communities. For example, in row 1 for "Rice sowed in Kgs", in column 5 the coefficient is 4.87*. The star shows that in RREP communities after electrification happened, rice sowed had increased significantly, at the 10 percent level.

Not all households in RREP villages connect to mini-grids (see Section 4.1 for more details connected households vs not connected households). Hence the comparison above, does not tell us the actual effect of having access to electricity for a household. In the results, in addition to comparing respondents in RREP to non RREP villages, we also report the impacts of electrification for those households that got connected. The Difference-in Differences then compare those households in RREP communities who connected to the mini-grid and those in non RREP/comparison households. The tables follow a similar format to the one discussed above.

Table 3 Example Difference in Difference Regression Analysis

	N (1)	Mean in Control in 2019 (2)	RREP vs Non RREP in 2019 (3)	Post (4)	Post × RREP (5)
Agricultural Output					
Rice sowed in Kgs	1000	60	−3.01	7.34***	4.87*
			(3)	(1)	(2)
Rice Harvested in Kgs	1000	234	−8.46	41.57***	4.23
			(22)	(8)	(11)
Rice sold in Kgs	1000	28	−3.93	7.64***	−0.78
			(6)	(2)	(3)
Cassava sowed in sticks	1000	859	−38.74	399.09***	129.26
			(173)	(96)	(126)
Cassava Harvested in Kgs	1000	367	−88.36	34.83	−50.94
			(64)	(29)	(48)
Cassava Sold in Kgs	1000	268	−70.90	13.11	−43.36
			(56)	(21)	(37)
Trees of cocoa sowed	1000	2	−1.00	2.87***	−1.73**
			(0.8)	(0.7)	(0.8)
Coco Harvested in Kgs	1000	64	−60.90**	1.72	−7.00
			(22)	(3)	(6)
Trees of coffee sowed	1000	5	−3.99	3.76*	−1.80
			(2)	(1)	(2)
Coffee Harvested in Kgs	1000	28	−21.73**	1.13	−5.11
			(8)	(2)	(5)

This is an example of a Difference in Difference estimation uses on all agricultural production from 2019 as the *pre* period and from 2020 as the *post* period. Includes district fixed effects and clustered standard errors at the village level.

4. Data Summary

In November and December of 2021, the impact evaluation team interviewed members of households in 194 communities across 14 of Sierra Leone's 16 districts. On average, each interview lasted around 2 hours, and covered diverse topics related to aspects of household life. For a copy of the survey instrument used in household interviews, please see Annex H. This impact evaluation aims to produce a holistic view of the effects of electrification on rural welfare and livelihood.

This section presents and summarizes the data collected in the Endline survey across all areas of interest. The data are then compared with data from the Baseline, conducted in June 2019, and using the methodology outlined in Section 3.7, we assess the effects of the RREP mini-grids on the households in those communities.

Section 4.1 presents results on household connections to the mini-grids in RREP communities. Section 4.2 discusses household energy use, specifically for lighting and cooking. Sections 4.3 and 4.4 address household income through agricultural and non-agricultural employment, respectively along with a breakdown of their time use during working hours. Section 4.5 presents data and results on assets such as livestock, land, and electrical appliances. Food security and household consumption is in Section 4.6.

4.1 WP1 Results

4.1.1 Connection to Minigrids

During the Endline survey we observe and record if households in RREP communities did in fact secure connections to the mini-grid, whether they are household connections and/or commercial connections. We find that of the 1,354 respondents in RREP communities which we re-sampled at Endline, 888 (65.4 percent) were connected, and 468 reported not being connected. Given that at Midline certain households selected into receiving the connections, we investigate whether this trend continues in Table 4. Columns 1-3 summarize the characteristics of connected households, and columns 4-6 summarize those not connected to mini-grids. Column 7 reports estimates from regressing each outcome on an indicator for being connected to the mini-grid using the Baseline sample. We find that connected households are less likely to be female headed, and to be larger households on average with fewer children under the ages of five. They are also more likely to be self employed, own land, own livestock, have more electric assets, spend more on food, and less likely to be food insecure.

This suggests that richer households select into electrification which may bias our results. Average intent-to-treat (ITT) estimates do not tell us the actual effect of having access to electricity: they examine the entire sample of households in RREP communities, whether or not those households have connected to the mini-grid. Therefore the complier sample, i.e those who secured connections to the mini-grid, provides more direct insight into the effects of electricity access.

Table 4: Baseline Differences Connected and Not connected Households who are assigned RREP

Baseline Differences Connected and Not connected Households in RREP communities

	Connected			Not Connected			
	Mean (1)	N= 888 Median (2)	SD (3)	Mean (4)	N= 468 Median (5)	SD (6)	Difference (7)
Household Demographics							
Female Headed Households	0.419	0	0.494	0.472	0	0.500	−0.052 ** (0.02)
Respondent has any disability	0.281	0	0.450	0.284	0	0.452	−0.000 (0.03)
Number of adults	2.857	2	2.160	2.323	2	1.832	0.532*** (0.14)
Number of children 0-5	1.058	1	1.202	1.052	1	1.147	−0.037 (0.05)
Employment							
Head employed in business	0.422	0	0.494	0.293	0	0.456	0.125*** (0.03)
Hours worked if business employed	5.706	5	4.160	5.457	5	3.891	0.494 (0.49)
Revenue from business in 1000s SLL	667.129	300	1138.513	852.639	300	1484.562	−133.368 (153.86)
Head Wage Employed	0.118	0	0.323	0.096	0	0.295	0.018 (0.02)
Hours worked in wage employment	5.943	6	3.084	4.981	5	3.099	0.625 (0.47)
Wage Income	877.819	625	1744.987	575.860	500	501.164	363.885 (278.78)
Assets							
Total Quantity of Electric Assets	2.483	2	3.033	1.530	1	2.061	0.997*** (0.16)
Radio	0.740	1	0.812	0.549	0	0.702	0.163*** (0.04)
Mobile phone	1.242	1	1.744	0.774	1	1.105	0.498*** (0.09)
If owns land	0.729	1	0.445	0.658	1	0.475	0.078 ** (0.03)
If owns Livestock	0.703	1	0.457	0.647	1	0.478	0.056 ** (0.02)
Food Security							
Food expenditures '000 SLL	181.597	150	128.584	151.005	130	109.059	31.794*** (6.97)
Ate less preferred food at least one day in the last week	0.450	0	0.498	0.526	1	0.500	−0.089*** (0.03)

Columns 1 to 3 report summary stats for households connected to the mini-grid at endline and 4 to 6 for not connected housheolds using baseline data from 2019. Column 7 reports the coefficient from regressing each outcome on an indicator for connected, the regression includes district fixed effects and clustered standard errors at the village level.

4.1.2 Energy Access and Use

Rural households create emissions mainly through the energy used for household lighting and cooking. Because the RREP project produces clean solar energy, RREP electrification aims to reduce CO_2 emission to the extent that households replace existing “dirty” households cooking and lighting technologies with clean solar-electrified technologies as long-term effects.

Households consume fuel for both cooking and lighting. Different fuel sources have different CO_2 emissions impacts. In this section we describe the energy sources used for household lighting and cooking. Electricity should reduce reliance on these “dirty” fuels. In the Midline Report we showed that a large majority of households use wood and charcoal as either a primary or secondary source of cooking energy. 81.6 percent of households get their primary or secondary source of cooking energy from collected firewood, while another 14.5 percent purchase charcoal, and 9.99 percent purchase firewood. In this section we investigate whether electricity access has led to people transitioning to cleaner sources of energy.

Tables 5 and 6 report Difference-in Difference estimates on main energy sources for lighting and cooking similar to the example presented earlier in the report. The first column of Table 5 reports the sample size, column 2 reports the average in households in the comparison communities in 2019 and column 3 is the average difference between households in RREP and comparison communities in 2019. Column 4 represents the added effect of the year 2021, and column 5 presents the interaction between the year and RREP status. The coefficients in column 5 indicate whether or not electrification created some sort of effect on the energy use. Table 5 reports results for the complier households, i.e households located in RREP communities which are connected to mini-grids in the Endline. For the rest of the report when the difference-in-difference estimates are presented, both the tables (the full sample intent to treat (ITT), and complier (LATE) sample) will be discussed together for overall significance of variables.

Table 5 finds that households in RREP communities are 3.4 percentage points less likely to have no light and **43 percentage points more likely to have light through the mini grid**; both these effects are statistically significant. As a result of having access to the grid, they are less likely to use lanterns,solar panels and candles as a source of light than households in non RREP communities.We also find that monthly expenditure on charcoal is 1546 Leones less for households in RREP communities, but since we see no corresponding changes to use of electric cook stoves or clean energy based technology we speculate that the decline could be a result of rising charcoal prices that may have lead households to make their own.

In Table 6 we find that connected households are 5.2 percentage points less likely to report having no light and **75 percentage points more likely to have light through the mini grid.** They are less likely to use a solar lantern when compared to 2019 usage rates, and the results show that households not connected to the mini-grid catch up over time so overall lantern usage rates are now similar. The same pattern holds for solar panels. For battery powered torch lights connected households are more likely to use it now than in 2019, but overall likelihood of usage is still lower when compared to households not connected to the mini-grid. Households connected to grids

spend less on charcoal and firewood on average, again this appears to be a function of them obtaining it themselves outside the market.

Table 5: Difference in Differences on Energy Use WP1 Communities

Difference in Differences on Energy Use WP1 Communities

	N	Mean in non RREP in 2019	RREP vs Non RREP in 2019	Post	Post × RREP
	(1)	(2)	(3)	(4)	(5)
Light Source					
No Light	3024	0.006	0.008	0.030 **	−0.034 **
			(0.01)	(0.01)	(0.02)
Mini Grid	3024	0.000	0.001	0.001	0.430***
			(0.01)	(0.00)	(0.03)
Kerosene	3024	0.001	−0.002	−0.002 *	0.002 *
			(0.00)	(0.00)	(0.00)
Firewood	3024	0.008	−0.002	−0.004	−0.000
			(0.00)	(0.00)	(0.01)
lantern	3024	0.373	0.157***	0.219***	−0.341***
			(0.03)	(0.04)	(0.05)
Solar panel	3024	0.041	0.031 *	0.028 **	−0.053***
			(0.02)	(0.01)	(0.02)
Battery	3024	0.530	−0.229***	−0.380***	0.112 **
			(0.03)	(0.03)	(0.05)
Generator	3024	0.018	0.005	−0.004	−0.009
			(0.01)	(0.00)	(0.01)
Candle	3024	0.003	0.003	−0.000	−0.004 **
			(0.00)	(0.00)	(0.00)
Phone Light	3024	0.011	0.012***	0.007	−0.010
			(0.00)	(0.01)	(0.01)
Expenditure on Energy Sources					
Monthly expenditure on Charcoal '000s of SLL'	2881	2.515	1.558 **	−1.614***	−1.546 **
			(0.74)	(0.46)	(0.76)
Monthly expenditure on Firewood '000s of SLL'	2876	4.058	1.924	−2.888***	−1.989
			(1.21)	(0.67)	(1.29)

Difference in Difference estimation uses electricity use from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects and clustered standard errors at the village level. The regression is weighted using Inverse Probability Weights.

Table 6: Difference in Differences on Energy Use Connected Households in RREP WP1 Communities

Difference in Differences on Energy Use Connected Households in RREP WP1 Communities

	N	Mean in Not Connected HHs in 2019	Connected vs Not Connected HHs in 2019	Post	Post × Not Connected
	(1)	(2)	(3)	(4)	(5)
Light Source					
No Light	2834	0.006	0.013 *	0.030***	−0.052 ***
			(0.01)	(0.01)	(0.01)
Mini Grid	2834	0.000	−0.000	0.001	0.747 ***
			(0.02)	(0.01)	(0.03)
Kerosene	2834	0.001	−0.002	−0.002	0.003
			(0.00)	(0.00)	(0.00)
Firewood	2834	0.008	−0.003	−0.004	−0.000
			(0.01)	(0.01)	(0.01)
lantern	2834	0.373	0.237 ***	0.219***	−0.447 ***
			(0.04)	(0.03)	(0.05)
Solar panel	2834	0.041	0.052 ***	0.028 **	−0.079 ***
			(0.02)	(0.01)	(0.02)
Battery	2834	0.530	−0.349 ***	−0.380***	0.195 ***
			(0.03)	(0.03)	(0.05)
Generator	2834	0.018	0.010	−0.004	−0.015
			(0.01)	(0.01)	(0.01)
Candle	2834	0.003	0.005	−0.000	−0.008
			(0.00)	(0.00)	(0.01)
Phone Light	2834	0.011	0.018 **	0.007	−0.013
			(0.01)	(0.01)	(0.01)
Expenditure on Energy Sources					
Monthly expenditure on Charcoal '000s of SLL'	2785	2.515	2.087 ***	−1.617 **	−2.069 *
			(0.78)	(0.66)	(1.11)
Monthly expenditure on Firewood '000s of SLL'	2781	4.058	2.882 **	−2.885***	−2.983 *
			(1.19)	(1.01)	(1.70)

Difference in Difference estimation uses electricity use from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects and clustered standard erros at the village level. The regression is weighted using Inverse Probability Weights.

4.1.3 Agriculture

This section presents findings on agricultural production and income. The measure of agricultural production focuses on one key staple crop (rice as this crop has gone through the entire cycle) and one cash crop (cocoa, similar to rice it has completed its crop cycle). The other crops are not discussed in this report as the Endline data collection happened before the end of the year, thus not capturing full cycles for the majority of crops.

As previously mentioned in the Midline report, during the Baseline survey in June 2019, the research team collected household survey level data on agricultural production for the 2018 calendar year. At the time of that data collection, the staple crops had not been harvested due to seasonality. Therefore, the research team gathered data on harvesting and selling of these crops for the year 2018, which was previously reported in the Baseline reports. In this report, we compare changes in agricultural production for 2019 to 2021. Data for 2019 was collected in the Midline Survey, and 2021 was collected in the Endline Survey. The data from the year 2019 is complete and covers the whole agricultural year, but the data from the Endline having been collected in November doesn't collect the whole agricultural year.

Table 7 Column 3 suggests that households in RREP communities were not different from comparison households in 2019 except that they sowed less cocoa and harvested less cocoa, which is in line with the Midline report previously submitted. Column 4 suggests that for households in both RREP and comparison communities quantities sold and harvested decreased in 2021 when compared to 2019. Column 5 finds that households in RREP communities are not different from comparison communities when it comes to rice sowed, harvested and sold, and cocoa sowed and harvested.

In Table 8, connected Households sow and harvest similar amounts of rice and cocoa on average in comparison to not connected households in 2021 when compared to 2019. When looking at columns 3-5 together we find that connected households catch up over time, neutralizing earlier differences with cocoa harvested.

Table 7: Difference in Differences Agricultural Outcomes WP1 Communities

Difference in Differences Agricultural Outcomes WP1 Communities

	N	Mean in non RREP in 2019	RREP vs Non RREP in 2019	Post	Post × RREP
	(1)	(2)	(3)	(4)	(5)
Agricultural Output					
Rice sowed in Kgs	1370	61.933	−5.577	3.682	3.275
			(4.49)	(4.24)	(5.85)
Rice Harvested in Kgs	1370	233.911	−17.890	−116.018 ***	16.505
			(24.30)	(17.42)	(26.42)
Rice sold in Kgs	1370	28.358	−4.726	−23.492 ***	4.982
			(6.53)	(5.26)	(6.86)
Trees of cocoa sowed	245	197.730	−182.678 *	−15.294	101.317
			(94.88)	(94.33)	(100.13)
Coco Harvested in Kgs	245	64.670	−57.790 **	−23.594	51.188
			(24.69)	(29.51)	(36.52)

Difference in Difference estimation uses agricultural data from from 2019 as the pre period and from 2021 as the post period. We only consider Rice and Cocoa because the agricultural seasons for these crops corresspond with our data collection. Includes district fixed effects and clustered standard erros at the village level. The regression is weighted using Inverse Probability Weights.

Table 8: Difference in Differences Agricultural Outcomes Connected Households in RREP WP1 Communities

Difference in Differences Agricultural Outcomes Connected Households in RREP WP1 Communities

	N	Mean in Not Connected HHs in 2019	Connected vs Not Connected HHs in 2019	Post	Post × Not Connected
	(1)	(2)	(3)	(4)	(5)
Agricultural Output					
Rice sowed in Kgs	1351	61.933	−6.911	3.619	3.236
			(6.82)	(4.80)	(8.57)
Rice Harvested in Kgs	1351	233.911	−25.929	−116.262 ***	23.655
			(25.81)	(18.19)	(32.47)
Rice sold in Kgs	1351	28.358	−6.285	−23.518 ***	6.667
			(5.48)	(3.86)	(6.90)
Trees of cocoa sowed	241	197.730	−281.633 ***	−14.752	148.775
			(68.68)	(52.34)	(94.53)
Coco Harvested in Kgs	241	64.670	−95.991 ***	−23.290	85.364 ***
			(23.50)	(17.90)	(32.34)

Difference in Difference estimation uses agricultural data from from 2019 as the pre period and from 2021 as the post period. We only consider Rice and Cocoa because the agricultural seasons for these crops corresspond with our data collection. Includes district fixed effects and clustered standard erros at the village level. The regression is weighted using Inverse Probability Weights.

4.1.4 Non-Agricultural Income

Electricity can be an engine of structural change, shifting rural economies from agrarian subsistence towards non-agricultural enterprises. We capture Endline measures of non-agricultural employment and existing uses of electricity, investigating how these outcomes differ across gender and disability status and between RREP and comparison communities.
Previously in the Midline Report, we reported that there were two types of small business owners in the data which has remained true in the Endline data. These types of businesses were those who had reasonable investment costs and revenues, and those 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.

Table 9 shows the difference-in-differences estimation on the Non-Ag Employment sample for the ITT, and Table 10 underneath shows the regression on the complier sample. Table 9 and 10 are consistent in that households in RREP communities are more likely to be self-employed and wage-employed, although this result is not statistically significant. Column 4 in both Tables suggests that there was a decline in hours worked in both wage employment and business, and a decline in revenues and wage income but an increase in likelihood of electricity use in wage work and businesses for both RREP and comparison households.

Table 9: Difference in Differences Non-Agricultural Outcomes WP1 Communities

Difference in Differences Non Ag Employment for WP1 communities

	N	Mean in non RREP in 2019	RREP vs Non RREP in 2019	Post	Post × RREP
	(1)	(2)	(3)	(4)	(5)
Non Agricultural Employment					
Head employed in business	2873	0.336	0.054**	−0.057***	0.002
			(0.03)	(0.02)	(0.03)
Hours worked if self employed	1095	5.712	−0.090	−1.552***	0.379
			(0.33)	(0.42)	(0.56)
Revenue from business in 1000s SLL	662	686.158	92.245	−583.632***	−115.038
			(137.03)	(103.20)	(129.10)
Cost from Business in 1000s SLL	669	540.813	85.869	−483.065***	−108.535
			(61.31)	(43.41)	(73.08)
Profit from Business in 1000s SLL	655	71.641	54.787	−4.823	−60.536
			(65.53)	(48.10)	(61.04)
Business uses electricty	886	0.218	0.044	0.236***	−0.024
			(0.04)	(0.05)	(0.07)
Head Wage Employed	2882	0.090	0.043	0.524***	0.167
			(0.08)	(0.18)	(0.34)
Hours worked in wage employment	319	5.926	−0.434	−1.591***	−0.410
			(0.47)	(0.45)	(0.67)
Wage Income in 1000s SLL	1634	859.119	−53.762	−847.503***	56.455
			(189.90)	(151.17)	(190.95)
Wage work uses electricity	267	0.267	0.075	0.279***	−0.013
			(0.05)	(0.06)	(0.08)

Difference in Difference estimation uses non agricultural employment from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects and clustered standard errors at the village level. The regression is weighted using Inverse Probability Weights.

Table 10: Difference in Differences Non-Agricultural Outcomes Connected Households in RREP WP1 Communities

Difference in Differences Non Ag Employment Connected Households in RREP WP1 Communities

	N	Mean in Not Connected HHs in 2019	Connected vs Not Connected HHs in 2019		Post		Post × Not Connected
	(1)	(2)	(3)		(4)		(5)
Non Agricultural Employment							
Head employed in business	2778	0.336	0.078	**	−0.057	*	0.010
			(0.04)		(0.03)		(0.05)
Hours worked if self employed	1056	5.712	−0.125		−1.546	***	0.565
			(0.60)		(0.54)		(0.80)
Revenue from business in 1000s SLL	630	686.158	125.701		−582.431	***	−153.350
			(139.77)		(145.38)		(214.42)
Cost from Business in 1000s SLL	636	540.813	143.237		−482.828	***	−176.712
			(90.84)		(95.49)		(140.51)
Profit from Business in 1000s SLL	624	71.641	53.255		−5.018		−58.153
			(76.07)		(78.37)		(115.84)
Business uses electricty	846	0.218	0.058		0.236	***	−0.032
			(0.06)		(0.06)		(0.09)
Head Wage Employed	2786	0.090	0.093		0.524		0.231
			(0.44)		(0.37)		(0.63)
Hours worked in wage employment	314	5.926	−0.702		−1.629	**	−0.406
			(0.91)		(0.77)		(1.15)
Wage Income in 1000s SLL	1535	859.119	−140.941		−848.185	***	153.166
			(124.74)		(83.75)		(129.63)
Wage work uses electricity	261	0.267	0.089		0.279	***	−0.008
			(0.12)		(0.11)		(0.16)

Difference in Difference estimation uses non agricultural employment from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects. The regression is weighted using Inverse Probability Weights.

4.1.5 Livestock, Land and Asset Ownership

4.1.5.1 Land

Land ownership is an important determinant of household wealth at Baseline, we captured pre-mini-grid levels of land ownership that includes residential and agricultural land, and similar variables were collected at Midline and Endline, enabling us to identify short-term electrification effects.

4.1.5.2 Livestock

Livestock is sometimes referred to as the "savings account" of the rural economy[24]. If electrification raises incomes – either through agricultural production or non-agricultural employment – households may invest some of this additional income in livestock. At Baseline, we captured pre-mini-grid levels of livestock ownership, and similar variables were collected at Midline and Endline, enabling us to identify short-term electrification effects. We collect data on the total number of animals owned, as well as the number of each type of animal owned. Animal ownership is defined as the right to kill or sell an animal. We also ask about the share of the household's animals which are (at least) jointly shared by women.

4.1.5.3 Electrified Assets

We expect to see substantial effects of community electrification on the ownership of electrified assets. In comparison communities, there was comparatively little reason for households to invest in assets which they cannot power between the Baseline and Midline surveys. In RREP communities, however, households were electrified in the interim, enabling them to use assets. In the Baseline report, we discussed findings from Focus Group Discussions that respondents were most looking forward to watching television and powering their DVD players. This was motivated by a desire to have closer families and for children to stay at home more often.
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. In communities where generators were owned, they were often used in 'cinemas' to show sports games, air compressors, or fridges. Maintenance was the main concern for generator owners, as they often had to travel to a large city to service it at a high cost.

Table 11 presents the difference-in-difference estimation on land, assets and livestock between the RREP and comparison communities over time. Table 12 reports the estimation for only those households in RREP communities who are connected to the solar mini-grid. Across both tables we find fairly consistent results. Households owning any livestock and total quantity of livestock owned has decreased in RREP communities relative to comparison communities. This may be indicative of households looking to invest away from agriculture and livestock with the surplus

[24] Doran, M. H., Low, A. R. C., & Kemp, R. L. (1979). Cattle as a store of wealth in Swaziland: Implications for livestock development and overgrazing in Eastern and Southern Africa. American Journal of Agricultural Economics, 61, 41-47. doi:10.2307/1239498; Randolph, T F et al. "Invited review: Role of livestock in human nutrition and health for poverty reduction in developing countries." Journal of animal science vol. 85,11 (2007): 2788-800. doi:10.2527/jas.2007-0467

from electricity access. Also notable are the negative results on the total number of electrical appliances owned and on the number of radios and mobile phones owned. These results are related: radios and mobile phones are the two most commonly owned assets in the entire sample, as they do not require constant electricity to operate and their batteries last for a long time. This result does not imply that households in RREP communities own fewer of these assets in 2021 than they did in 2019; it indicates that rates of ownership for comparison communities caught up to the rates in RREP communities. Because mobile phones and radios are commonly purchased even when households do not have regular access to electricity, households in RREP communities may have become “saturated" with these assets prior to electrification.

The change in ownership of freezers is also significant but positive, indicating that the rate of freezer ownership by households in RREP communities increased relatively more than in comparison communities. This is consistent with theory. Freezers require more regular electricity access to operate, compared to radios or mobile phones, and draw more electricity. It would be difficult to operate a freezer in the comparison communities, but the mini-grids in RREP communities offer the opportunity to operate productive assets such as these. In the non agricultural income section, we presented survey data and qualitative results indicating that many business owners see selling cold drinks as a potentially lucrative market. The significantly increased rates of freezer ownership indicate that these entrepreneurs may be realizing their plans.

We also find promising evidence that households may begin to invest in assets such as televisions, that while not significant for productive use, are useful indicators of happiness, life satisfaction and investment in leisure.

Table 11: Difference in Differences Land, Assets and Livestock in WP1 Communities

Difference in Differences Land, Assets and Livestock WP1 Communities

	N	Mean in non RREP in 2019	RREP vs Non RREP in 2019	Post	Post × RREP
	(1)	(2)	(3)	(4)	(5)
Land Ownership					
If owns land	2874	0.689	0.026	0.018	−0.036
			(0.03)	(0.03)	(0.04)
Land Owned in acres	2816	6.834	−0.298	−3.124***	0.097
			(1.29)	(1.09)	(1.35)
Livestock					
Owns any livestock	3024	0.660	0.073 **	0.001	−0.130***
			(0.03)	(0.03)	(0.04)
Percent of livestock owned or shared by women	1037	0.643	−0.015	0.122 **	−0.058
			(0.03)	(0.05)	(0.08)
Total livestock owned	2158	6.154	2.928***	−4.730***	−3.088***
			(0.51)	(0.53)	(0.76)
Owns pig	1923	0.012	0.012	0.117	−0.113
			(0.01)	(0.11)	(0.11)
Owns cow	1045	0.040	0.024	0.878***	0.007
			(0.02)	(0.06)	(0.06)
Owns duck	1923	0.048	−0.001	0.042 *	0.125
			(0.03)	(0.02)	(0.12)
Owns sheep	1226	0.239	0.046	0.735***	−0.055
			(0.03)	(0.03)	(0.04)
Owns goat	1421	0.401	0.075 **	0.623***	−0.076 *
			(0.04)	(0.03)	(0.04)
Owns chick	1925	0.790	−0.004	0.078 **	0.088
			(0.04)	(0.03)	(0.12)
Electrical Assets					
Total Quantity of Electric Assets	3024	1.786	0.763***	0.363***	−0.347 **
			(0.17)	(0.12)	(0.17)
Electric fan	3024	0.030	0.032***	0.014 *	0.006
			(0.01)	(0.01)	(0.01)
Stove (electric)	3024	0.002	0.000	0.001	0.004
			(0.00)	(0.00)	(0.00)
Freezer	3024	0.032	0.028***	0.005	0.047***
			(0.01)	(0.00)	(0.01)
Sewing Machine	3024	0.040	0.011	−0.006	−0.011
			(0.01)	(0.01)	(0.01)
Stereo system	3024	0.037	0.021 *	0.033***	0.011
			(0.01)	(0.01)	(0.02)
Television	3024	0.082	0.056***	−0.002	0.027 *
			(0.02)	(0.01)	(0.01)
Video/DVD equipment	3024	0.092	0.048***	0.028 *	−0.001
			(0.02)	(0.02)	(0.02)
Radio	3024	0.578	0.175***	0.052	−0.143***
			(0.04)	(0.03)	(0.05)
Mobile phone	3024	0.900	0.382***	0.229***	−0.300***
			(0.10)	(0.07)	(0.11)

Difference in Difference estimation uses land, livestock and asset ownership from from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects and clustered standard errors at the village level. The regression is weighted using Inverse Probability Weights.

Table 12: Difference in Differences Land, Assets and Livestock Connected Households in RREP WP1 Communities

Difference in Differences Land, Assets and Livestock Connected Households in RREP WP1 Communities

	N	Mean in Not Connected HHs in 2019	Connected vs Not Connected HHs in 2019	Post	Post × Not Connected
	(1)	(2)	(3)	(4)	(5)
Land Ownership					
If owns land	2778	0.689	0.061 *	0.018	−0.076
			(0.04)	(0.03)	(0.05)
Land Owned in acres	2721	6.834	−0.142	−3.122***	−0.163
			(1.20)	(1.01)	(1.70)
Livestock					
Owns any livestock	2834	0.660	0.141 ***	0.001	−0.114 **
			(0.04)	(0.03)	(0.05)
Percent of livestock owned or shared by women	987	0.643	−0.027	0.127	−0.094
			(0.04)	(0.12)	(0.20)
Total livestock owned	1969	6.154	5.017 ***	−4.720***	−5.038 ***
			(0.65)	(0.72)	(1.33)
Owns pig	1873	0.012	0.019	0.117	−0.165
			(0.09)	(0.08)	(0.12)
Owns cow	995	0.040	0.035 *	0.882***	0.016
			(0.02)	(0.06)	(0.10)
Owns duck	1873	0.048	0.003	0.041	0.178
			(0.20)	(0.17)	(0.28)
Owns sheep	1177	0.239	0.061 *	0.738***	−0.075
			(0.04)	(0.05)	(0.08)
Owns goat	1371	0.401	0.132 ***	0.624***	−0.136 **
			(0.04)	(0.04)	(0.07)
Owns chick	1875	0.790	−0.003	0.077	0.127
			(0.20)	(0.17)	(0.28)
Electrical Assets					
Total Quantity of Electric Assets	2834	1.786	1.208 ***	0.363 **	−0.129
			(0.20)	(0.16)	(0.28)
Electric fan	2834	0.030	0.047 *	0.014	0.024
			(0.03)	(0.02)	(0.04)
Stove (electric)	2834	0.002	−0.000	0.001	0.007
			(0.01)	(0.00)	(0.01)
Freezer	2834	0.032	0.046 **	0.005	0.089 ***
			(0.02)	(0.02)	(0.03)
Sewing Machine	2834	0.040	0.026	−0.006	−0.018
			(0.02)	(0.02)	(0.03)
Stereo system	2834	0.037	0.034	0.033 *	0.034
			(0.02)	(0.02)	(0.03)
Television	2834	0.082	0.092 ***	−0.002	0.061
			(0.03)	(0.02)	(0.04)
Video/DVD equipment	2834	0.092	0.074 ***	0.028	0.027
			(0.03)	(0.02)	(0.04)
Radio	2834	0.578	0.296 ***	0.052	−0.135 *
			(0.06)	(0.05)	(0.08)
Mobile phone	2834	0.900	0.587 ***	0.229***	−0.256 *
			(0.10)	(0.09)	(0.14)

Difference in Difference estimation uses land, livestock and asset ownership from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects. The regression is weighted using Inverse Probability Weights.

4.1.6 Food Security, Consumption

Table 13 reports the difference-in-difference estimation of food consumption and food security measures from Baseline to Endline. Table 14 reports the same outcomes for the complier population. Overall, the households in RREP communities have negative coefficients on food expenditures. Amount spent on meat has dropped significantly at the 10 percent, fruit and fish at the 5 percent level suggesting that the households are more willing to consume less preferred foods right now. This suggests that access to electricity might push households to substitute out of food expenditures. While we don't have data on non-food expenditure it is likely that households are diverting funds away from food.

While households in RREP communities are spending less on food, they don't do worse than households in comparison communities on food security measures. This could suggest that while they are spending less on certain foods they may not be reducing quantities consumed. It is possible that food commodities become cheaper in these communities as a result of electricity access, resulting from efficiency gains in food storage.

Table 13: Difference in Differences Consumption and Food Expenditure in WP1 Communities

Difference in Differences Consumption and Food Expenditure Outcomes WP1 communities

	N	Mean in non RREP in 2019	RREP vs Non RREP in 2019	Post	Post × RREP
	(1)	(2)	(3)	(4)	(5)
Consumption Expenditure					
Food expenditures '000 SLL in the past week	3024	160.490	16.827 **	36.929***	−22.195 **
			(7.72)	(7.35)	(10.40)
Expenditure on staples	2984	62.239	2.750	14.630***	−3.878
			(3.70)	(3.65)	(5.19)
Expenditure on vegetables	2999	30.853	4.421 *	3.036	−4.314
			(2.48)	(2.25)	(2.95)
Expenditure on fish	2996	8.747	3.354 **	−1.131	−4.337***
			(1.37)	(0.80)	(1.55)
Expenditure on meat	3000	32.794	3.273 *	3.342 **	−3.484 *
			(1.67)	(1.39)	(2.09)
Expenditure on fruit	2998	5.346	3.225***	−1.682***	−3.260***
			(0.90)	(0.57)	(0.95)
Expenditure on other foods	2984	23.445	4.056 **	19.021***	−7.348 **
			(1.95)	(2.20)	(2.98)
Consumption Expenditure IHS Transformation					
Food Expenditures in the past week	3024	5.514	0.006	−0.036	−0.242 *
			(0.07)	(0.11)	(0.14)
Expenditure on staples	2984	4.456	−0.036	−0.423***	0.022
			(0.08)	(0.13)	(0.18)
Expenditure on vegetables	2999	3.436	0.304 **	0.497***	−0.441***
			(0.12)	(0.13)	(0.16)
Expenditure on fish	2996	1.135	0.323 **	−0.106	−0.401 **
			(0.14)	(0.11)	(0.18)
Expenditure on meat	3000	3.914	0.026	−0.049	−0.176
			(0.06)	(0.08)	(0.11)
Expenditure on fruit	2998	1.076	0.530***	−0.188 *	−0.559***
			(0.13)	(0.11)	(0.15)
Expenditure on other foods	2984	3.181	0.247	0.933***	−0.464 **
			(0.15)	(0.15)	(0.20)
Food Security					
Ate less preferred food at least one day in the last week	3024	0.481	0.012	−0.265***	−0.098 **
			(0.03)	(0.04)	(0.05)
Reduced portion sizes for members of household	3024	0.439	0.074 **	−0.277***	−0.095 **
			(0.04)	(0.03)	(0.04)
Asked relative or friend for help with food at least once in the past week	3024	0.329	0.039	−0.212***	−0.057 *
			(0.03)	(0.03)	(0.03)
Went one or more days with no meals in the past week	3021	0.151	−0.008	−0.118***	0.007
			(0.02)	(0.02)	(0.03)

Difference in Difference estimation uses consumption and food security from from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects and clustered standard erros at the village level. The regression is weighted using Inverse Probability Weights.

Table 14: Difference in Differences Consumption and Food Expenditure Connected Households in RREP WP1 Communities

Difference in Differences Consumption and Food Expenditure Outcomes Connected Households in RREP WP1 Communities

	N	Mean in Not Connected HHs in 2019	Connected vs Not Connected HHs in 2019	Post	Post × Not Connected
	(1)	(2)	(3)	(4)	(5)
Consumption Expenditure					
Food expenditures '000 SLL in the past week	2834	160.490	30.148***	36.929***	−1.933
			(7.77)	(6.51)	(10.98)
Expenditure on staples	2797	62.239	6.616	14.645***	6.481
			(4.15)	(3.49)	(5.87)
Expenditure on vegetables	2812	30.853	7.973***	3.036*	−1.562
			(2.16)	(1.81)	(3.05)
Expenditure on fish	2810	8.747	5.481***	−1.131	−6.007***
			(1.22)	(1.02)	(1.72)
Expenditure on meat	2813	32.794	5.616***	3.342**	0.935
			(1.70)	(1.42)	(2.40)
Expenditure on fruit	2810	5.346	4.912***	−1.682***	−4.569***
			(0.68)	(0.57)	(0.96)
Expenditure on other foods	2798	23.445	6.245***	19.021***	−3.899
			(1.79)	(1.49)	(2.53)
Consumption Expenditure IHS Transformation					
Food Expenditures in the past week	2834	5.514	0.057	−0.036	0.617***
			(0.07)	(0.06)	(0.10)
Expenditure on staples	2797	4.456	0.007	−0.422***	0.768***
			(0.11)	(0.09)	(0.16)
Expenditure on vegetables	2812	3.436	0.502***	0.497***	0.006
			(0.09)	(0.07)	(0.12)
Expenditure on fish	2810	1.135	0.527***	−0.106	−0.489***
			(0.13)	(0.11)	(0.19)
Expenditure on meat	2813	3.914	0.064	−0.049	0.441***
			(0.07)	(0.06)	(0.09)
Expenditure on fruit	2810	1.076	0.796***	−0.188**	−0.718***
			(0.11)	(0.09)	(0.15)
Expenditure on other foods	2798	3.181	0.377***	0.933***	0.041
			(0.09)	(0.08)	(0.13)
Food Security					
Ate less preferred food at least one day in the last week	2834	0.481	0.018	−0.265***	−0.127***
			(0.03)	(0.03)	(0.05)
Reduced portion sizes for members of household	2834	0.439	0.128***	−0.277***	−0.135***
			(0.03)	(0.03)	(0.05)
Asked relative or friend for help with food at least once in the past week	2834	0.329	0.061**	−0.212***	−0.074*
			(0.03)	(0.03)	(0.04)
Went one or more days with no meals in the past week	2832	0.151	−0.021	−0.118***	0.027
			(0.02)	(0.02)	(0.03)

Difference in Difference estimation uses consumption and food security from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects.

4.1.7 Time Use and Life Satisfaction

Access to electricity, and electric technology has potential to change the time disposition of households. They may be able to finish tedious work faster, reducing time spent on cooking or chores, they may also re-allocate time to leisure activities if mechanisation of work frees up time for other activities. Alternatively if prior to electrification the household had meek prospects for work, electricity access may increase their time investment in productive activities. Access to leisure time, and technology such as phones and television sets as well as other avenues for entertainment could transform people's perception of life satisfaction, general happiness and mental health.

Table 15 reports estimations on the impact of the mini-grid on time use and life satisfaction measures. We find that households in RREP sites are substituting out of leisure and chores on average, and spending more time on the farm after having access to electricity when compared to households in non RREP sites. We see no impact on the time spent on wage employment or on the business.We also find that on average households in RREP sites report a higher level of life satisfaction than households in comparison communities after receiving access to electricity. Table 16 reports on the same measures for households in RREP sites who are connected to the mini-grid.We find similar results for households connected to the grid- they spend on average one hour longer on the farm per day, and report a higher score on a life satisfaction index. This is suggestive evidence that access to electricity might enable people to work longer in their farms, and also improve overall life satisfaction.

Table 15: Difference in Differences Time Use and Life Satisfaction in WP1 Communities

Difference in Differences Time Use and Life Satisfaction Outcomes WP1 communities

	N	Mean in non RREP in 2019	RREP vs Non RREP in 2019	Post	Post × RREP
	(1)	(2)	(3)	(4)	(5)
Time Use					
Average hours spent by respondent on leisure per day	3024	2.910	0.335 **	−0.008	−0.476 **
			(0.16)	(0.16)	(0.22)
Average hours spent by respondent on chores per day	3024	1.175	0.384***	−0.043	−0.405***
			(0.10)	(0.08)	(0.12)
Average hours spent by respondent on farm per day	3024	4.599	−1.380***	−1.017***	0.525 *
			(0.34)	(0.17)	(0.27)
Average hours spent by respondent on business per day	3024	2.002	0.491 **	−0.059	−0.332
			(0.24)	(0.17)	(0.23)
Average hours spent by respondent on wage per day	3024	0.436	−0.072	0.043	0.016
			(0.10)	(0.10)	(0.13)
Life Satisfaction					
Respondent is very happy with life	2880	0.287	0.029	−0.104***	−0.004
			(0.03)	(0.03)	(0.04)
Respondent is very unhappy with life	2880	0.067	0.010	0.005	−0.009
			(0.01)	(0.01)	(0.02)
Index of Life Satisfaction	2867	0.012	−0.076	−0.087	0.219 **
			(0.07)	(0.08)	(0.11)
Feels in control all the time	2864	0.063	0.043 **	0.030 *	−0.047 *
			(0.02)	(0.02)	(0.03)
Very worried about finding work	2842	0.646	−0.050	0.077 **	0.053
			(0.03)	(0.04)	(0.05)
Very worried about money for basic needs	2872	0.760	−0.047	0.117***	0.017
			(0.03)	(0.03)	(0.04)

Difference in Difference estimation uses time use and life satisfaction from from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects and clustered standard erros at the village level. The regression is weighted using Inverse Probability Weights.

Table 16: Difference in Differences Time Use and Life Satisfaction Connected Households in RREP WP1 Communities

Difference in Differences Time Use and Life Satisfaction, Connected Households in RREP WP1 Communities

	N	Mean in Not Connected HHs in 2019	Connected vs Not Connected HHs in 2019	Post	Post × Not Connected
	(1)	(2)	(3)	(4)	(5)
Time Use					
Average hours spent by respondent on leisure per day	2834	2.910	0.557 **	−0.008	−0.251
			(0.24)	(0.20)	(0.33)
Average hours spent by respondent on chores per day	2834	1.175	0.518 ***	−0.043	−0.379 *
			(0.14)	(0.12)	(0.20)
Average hours spent by respondent on farm per day	2834	4.599	−1.946 ***	−1.017***	1.325 ***
			(0.32)	(0.27)	(0.46)
Average hours spent by respondent on business per day	2834	2.002	0.649 **	−0.059	−0.047
			(0.27)	(0.22)	(0.38)
Average hours spent by respondent on wage per day	2834	0.436	−0.146	0.043	0.147
			(0.14)	(0.12)	(0.20)
Life Satisfaction					
Respondent is very happy with life	2784	0.287	0.053	−0.104***	−0.014
			(0.03)	(0.03)	(0.05)
Respondent is very unhappy with life	2784	0.067	0.010	0.005	−0.009
			(0.02)	(0.02)	(0.03)
Index of Life Satisfaction	2773	0.012	−0.087	−0.087	0.309 ***
			(0.08)	(0.06)	(0.11)
Feels in control all the time	2770	0.063	0.060 ***	0.030 *	−0.066 **
			(0.02)	(0.02)	(0.03)
Very worried about finding work	2750	0.646	−0.081 **	0.077 **	0.085 *
			(0.04)	(0.03)	(0.05)
Very worried about money for basic needs	2777	0.760	−0.065 **	0.117***	0.018
			(0.03)	(0.03)	(0.04)

Difference in Difference estimation uses time use from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects. The regression is weighted using Inverse Probability Weights.

4.2 WP2 Results

WP2 communities are on average larger and wealthier than WP1 communities. Given this underlying difference it is necessary to analyse the impact of electrification for each work package separately because it is likely that households in these sites respond differently. Additionally, WP2 communities were electrified later than WP1 communities, and many of the communities have not been electrified/ a grid has not been installed- only 14 WP2 communities have been electrified. This complicates the Instrumental variables estimation, because we would not have a strong first stage that could be used as an instrument for peoples connection to the grid. We have hence limited our analyses of WP2 communities just to the ITT which studies the impact of being in an RREP site and not necessarily the impact of having a connection to the grid.

4.2.1 Connection to Minigrids

Similar to WP1 RREP households, during the Endline we observe and record if households in RREP WP2 communities did in fact secure connections to the mini-grid, whether they are household connections and/or commercial connections. We find that of the 1,632 respondents in RREP communities which we re-sampled at Endline, 548 (33.6 percent) were connected, and 1084 reported not being connected. This number is low, we find through the key informant interviews with operators that this is because many of the grids have not been installed, and in some communities the grid is not electrified yet.

Given that in WP1 communities certain households are selected into receiving the connections, we investigate whether this trend continues in WP2 households that are in RREP sites. In Table 17 we find that connected households are less likely to be female headed, and to be larger households on average. They also have more business revenue on average, own land, own livestock, have more electric assets, spend more on food, and are less likely to be food insecure.

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Table 17: Baseline Differences Connected and Not connected Households who are assigned to RREP

Baseline Differences Connected and Not connected Households in RREP communities

	Connected			Not Connected			
	Mean (1)	N= 548 Median (2)	SD (3)	Mean (4)	N= 1084 Median (5)	SD (6)	Difference (7)
Household Demographics							
Female Headed Households	1.268	1	0.443	1.301	1	0.459	−0.060 *
							(0.03)
Respondent has any disability	0.235	0	0.425	0.195	0	0.396	0.013
							(0.03)
Number of adults	3.358	3	1.545	3.359	3	1.752	0.247 **
							(0.10)
Number of children 0-5	0.932	1	0.957	0.962	1	1.062	0.012
							(0.07)
Employment							
Head employed in business	0.700	1	4.198	0.457	0	0.498	0.263
							(0.16)
Hours worked if business employed	6.233	5	4.318	6.311	6	4.272	0.287
							(0.44)
Revenue from business in 1000s SLL	1428.111	500	2982.164	1418.913	500	3207.652	547.351 **
							(207.94)
Head Wage Employed	0.321	0	4.195	0.294	0	4.257	0.114
							(0.24)
Hours worked in wage employment	5.469	5	2.628	6.159	6	3.182	−0.390
							(0.64)
Wage Income	678.003	640	461.429	686.640	600	563.210	16.986
							(120.32)
Assets							
Total Quantity of Electric Assets	2.633	2	2.871	2.173	2	2.291	1.062***
							(0.21)
Radio	0.741	1	0.699	0.600	1	0.689	0.164***
							(0.05)
Mobile phone	1.363	1	1.469	1.285	1	1.360	0.452***
							(0.12)
If owns land	0.672	1	0.470	0.602	1	0.490	0.093***
							(0.03)
If owns Livestock	0.693	1	0.461	0.649	1	0.477	0.045 *
							(0.03)
Food Security							
Food expenditures '000 SLL	137.170	132	63.080	142.642	140	59.968	7.537 **
							(3.41)
Ate less preferred food at least one day in the last week	0.414	0	0.493	0.387	0	0.487	−0.061
							(0.04)

Columns 1 to 3 report summary stats for households connected to the mini-grid at endline and 4 to 6 for not connected housheolds using baseline data from 2019. Column 7 reports the coefficient from regressing each outcome on an indicator for connected, the regression includes district fixed effects and clustered standard errors at the village level.

4.2.2 Energy Access and Use

Table 18 suggests that households in RREP sites are 23 percentage points more likely to be using the mini-grid for light than households in comparison communities. These households are 20 percentage points less likely to use a solar lantern for light, and 2.7 percentage points less likely to use a generator for light, this is to be expected because households are now using the mini-grid for their energy needs. Similar to WP1 households we find that households in RREP sites are spending less on charcoal and firewood on average. We see that there has been a general decline in expenditure for firewood and charcoal for both RREP and comparison households based on column 4. While this looks promising, it is not indicative of a transition from firewood and charcoal to more cleaner energy sources, because there is no evidence of households owning electricity based technology for cooking or other needs. We do have anecdotal evidence from field observations and qualitative interviews that suggest that because of a hike in prices households are now procuring their own firewood and making their own charcoal.

Table 18: Difference in Differences on Energy Use WP2 Communities

Difference in Differences on Energy Use WP2

	N	Mean in non RREP in 2019	RREP vs Non RREP in 2019	Post	Post × RREP
	(1)	(2)	(3)	(4)	(5)
Light Source					
No Light	3559	0.001	−0.001	0.018	−0.001
			(0.00)	(0.01)	(0.01)
Mini Grid	3559	0.002	0.005	−0.001	0.230 ***
			(0.02)	(0.00)	(0.04)
Kerosene	3559	0.001	−0.002 **	−0.001	0.001
			(0.00)	(0.00)	(0.00)
Firewood	3559	0.006	−0.006 **	0.003	−0.003
			(0.00)	(0.01)	(0.01)
lantern	3559	0.470	0.039	0.122 **	−0.201 ***
			(0.05)	(0.05)	(0.07)
Solar panel	3559	0.040	0.019 *	0.032 ***	−0.015
			(0.01)	(0.01)	(0.01)
Battery	3559	0.432	−0.077	−0.239 ***	−0.008
			(0.05)	(0.04)	(0.05)
Generator	3559	0.022	0.031 ***	−0.000	−0.027 ***
			(0.01)	(0.00)	(0.01)
Candle	3559	0.002	−0.003 **	−0.001	0.000
			(0.00)	(0.00)	(0.00)
Phone Light	3559	0.009	0.001	−0.003	−0.002
			(0.00)	(0.00)	(0.00)
Expenditure on Energy Sources					
Monthly expenditure on Charcoal '000s of SLL'	3415	5643.173	5431.910 ***	−3067.083 ***	−5373.329 ***
			(1475.38)	(871.79)	(1543.16)
Monthly expenditure on Firewood '000s of SLL'	3415	6355.344	3935.321 ***	−4464.058 ***	−3881.839 **
			(1431.66)	(995.59)	(1597.11)

Difference in Difference estimation uses electricity use from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects and clustered standard errors at the village level. The regression is weighted using Inverse Probability Weights.

4.2.3 Agriculture

To measure the impact of being in an RREP site on agricultural output we leverage data from the 2019 agricultural cycle and the 2021 agricultural cycle. The data for both cycles was collected during the endline data collection, while the 2019 data is complete the 2021 data could be missing information for crops that haven't finished their cycle by November. We hence restrict our analysis to rice and cocoa, both of which finish harvests by November. We find below that households in WP2 communities that were in RREP sites did not see major effects of electrification. We can hence conclude that households in RREP sites did not experience any measurable gains in agricultural output.

Table 19: Difference in Differences Agricultural Outcomes WP2 Communities

Difference in Differences Agricultural Outcomes WP2 Communities

	N	Mean in non RREP in 2019	RREP vs Non RREP in 2019	Post	Post × RREP
	(1)	(2)	(3)	(4)	(5)
Agricultural Output					
Rice sowed in Kgs	2132	68.731	−4.066	2.019	−4.228
			(4.70)	(2.78)	(3.71)
Rice Harvested in Kgs	2132	297.382	−34.958	−155.835 ***	3.565
			(27.34)	(27.78)	(30.92)
Rice sold in Kgs	2132	25.141	−2.358	−19.783 ***	2.645
			(5.71)	(5.23)	(5.92)
Trees of cocoa sowed	475	81.320	−6.255	73.288 ***	−8.651
			(13.22)	(16.64)	(23.90)
Coco Harvested in Kgs	475	39.442	−9.626	18.947 ***	−3.316
			(9.23)	(4.17)	(5.74)

Difference in Difference estimation uses agricultural data from from 2019 as the pre period and from 2021 as the post period. We only consider Rice and Cocoa because the agricultural seasons for these crops corresspond with our data collection. Includes district fixed effects and clustered standard erros at the village level.

4.2.4 Non-Agricultural Income

Table 20 presents results about the effect of being in an RREP community on non agricultural employment. Similar to WP1 communities, households in WP2 RREP sites do not see any effects of having access to the mini-grid on non-agricultural employment measures. This could be because a lot of the mini-grids have not been electrified but also because it takes time to see effects on employment outcomes.

Table 20: Difference in Differences Non-Agricultural Outcomes WP2 Communities

Difference in Differences Non Ag Employment for WP2 communities

	N	Mean in non RREP in 2019	RREP vs Non RREP in 2019	Post	Post × RREP
	(1)	(2)	(3)	(4)	(5)
Non Agricultural Employment					
Head employed in business	3408	0.494	1.025	0.253 ***	0.912
			(0.94)	(0.06)	(0.97)
Hours worked if self employed	1623	6.027	0.380	2.545 ***	0.266
			(0.36)	(0.32)	(0.43)
Revenue from business in 1000s SLL	1303	1421.868	90.490	1296.456 ***	19.854
			(245.08)	(200.41)	(278.78)
Cost from Business in 1000s SLL	1303	615.979	34.704	592.408 ***	55.702
			(61.39)	(51.15)	(72.43)
Profit from Business in 1000s SLL	1303	277.521	221.566***	304.013 *	49.335
			(83.31)	(177.52)	(218.25)
Business uses electricty	1202	0.344	0.018	0.017	0.154
			(0.17)	(0.18)	(0.20)
Head Wage Employed	3417	0.211	1.510	0.573 ***	1.688
			(1.05)	(0.20)	(1.12)
Hours worked in wage employment	402	5.911	0.163	1.670 ***	0.338
			(0.40)	(0.45)	(0.61)
Wage Income in 1000s SLL	1954	664.345	117.192 *	543.207 ***	96.743
			(67.61)	(35.65)	(67.25)
Wage work uses electricity	314	0.882	0.925 *	0.334 *	0.374
			(0.55)	(0.17)	(0.89)

Difference in Difference estimation uses electricity use from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects and clustered standard errors at the village level. The regression is weighted using Inverse Probability Weights.

4.2.5 Livestock, Land and Asset Ownership

Table 21 below displays the difference-in-difference estimation on land, assets and livestock between the RREP and comparison communities. Similar to the WP1 communities we see that the households owning any livestock and total quantity of livestock owned has decreased in RREP communities relative to comparison communities, though none of these results are significant. There are also negative results on the total number of electrical appliances owned and on the number of radios and mobile phones owned which indicates that rates of ownership for comparison communities caught up to the rates in RREP communities. The ownership of freezers are seen to be higher in RREP communities, though again these results are not significant. This does seem to remain consistent over time that the comparison communities are not catching up in this electrified asset due to how much electricity usage the refrigerators would need in comparison to smaller electrical appliances such as a phone or radio.

Table 21: Difference in Differences Land, Assets and Livestock in WP2 Communities

Difference in Differences Land, Assets and Livestock WP2 Communities

	N	Mean in non RREP in 2019	RREP vs Non RREP in 2019	Post	Post × RREP
	(1)	(2)	(3)	(4)	(5)
Land Ownership					
If owns land	3410	0.649	−0.029	0.078 **	0.022
			(0.03)	(0.03)	(0.04)
Land Owned in acres	3379	2.003	−0.793 **	1.399***	−0.078
			(0.34)	(0.46)	(0.60)
Livestock					
Owns any livestock	3558	0.668	0.009	−0.053 **	−0.007
			(0.03)	(0.02)	(0.03)
Percent of livestock owned or shared by women	1392	0.805	0.067	0.113	−0.076
			(0.09)	(0.08)	(0.09)
Total livestock owned	2718	7.087	1.188 **	−4.317***	−1.015
			(0.57)	(0.67)	(1.20)
Owns pig	2280	0.011	0.010	0.003	−0.006
			(0.01)	(0.01)	(0.01)
Owns cow	1252	0.061	0.033	0.678***	−0.013
			(0.03)	(0.08)	(0.04)
Owns duck	2281	0.112	0.034 **	0.016	−0.023
			(0.01)	(0.01)	(0.02)
Owns sheep	1446	0.232	0.026	0.737***	−0.038
			(0.03)	(0.03)	(0.04)
Owns goat	1625	0.373	−0.054 *	0.578***	0.037
			(0.03)	(0.03)	(0.04)
Owns chick	2282	0.893	−0.012	0.088	−0.061
			(0.02)	(0.09)	(0.09)
Electrical Assets					
Total Quantity of Electric Assets	3559	1.939	1.008***	0.211 **	−0.328 *
			(0.15)	(0.08)	(0.18)
Electric fan	3559	0.028	0.048***	0.003	0.013
			(0.01)	(0.00)	(0.01)
Freezer	3559	0.028	0.043***	0.006	0.020
			(0.01)	(0.00)	(0.01)
Sewing Machine	3559	0.055	0.032 *	−0.015 *	−0.010
			(0.02)	(0.01)	(0.02)
Stereo system	3559	0.048	0.039 **	0.017 *	0.024
			(0.01)	(0.01)	(0.02)
Television	3559	0.058	0.052***	0.006	0.026
			(0.01)	(0.01)	(0.02)
Video/DVD equipment	3559	0.086	0.063***	0.028 **	−0.001
			(0.02)	(0.01)	(0.02)
Radio	3559	0.593	0.153***	0.038	−0.078 *
			(0.03)	(0.03)	(0.04)
Mobile phone	3559	1.070	0.580***	0.119 **	−0.353***
			(0.08)	(0.05)	(0.10)

Difference in Difference estimation uses electricity use from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects and clustered standard errors at the village level. The regression is weighted using Inverse Probability Weights.

4.2.6 Food Security, Consumption

Similar to the WP1 communities, households residing in RREP communities have negative coefficients on consumption expenditures, although none of these results are significant as shown in Table 22. While households in RREP communities are consuming slightly less than the comparison households, this does not mean that they are overall more food insecure as none of the results are significant nor are the coefficients negative aside from a reduction in portion size.

Table 22: Difference in Differences Consumption and Food Expenditure in WP2 Communities

Difference in Differences Consumption and Food Expenditure Outcomes WP2 communities

	N	Mean in non RREP in 2019	RREP vs Non RREP in 2019	Post	Post × RREP
	(1)	(2)	(3)	(4)	(5)
Consumption Expenditure					
Food expenditures '000 SLL in the past week	3559	136.094	11.054**	50.203***	15.811
			(5.27)	(7.74)	(10.02)
Expenditures '000 SLL	3531	58.230	3.196	14.865***	8.533
			(2.59)	(4.23)	(5.36)
Expenditures '000 SLL	3516	22.203	2.047**	10.173***	2.665
			(1.00)	(1.24)	(1.78)
Expenditures '000 SLL	3542	4.972	1.670**	0.816	−0.101
			(0.67)	(0.58)	(0.85)
Expenditures '000 SLL	3527	23.855	1.570	11.584***	1.474
			(1.06)	(1.20)	(1.84)
Expenditures '000 SLL	3552	2.614	0.864**	−0.139	−0.179
			(0.38)	(0.36)	(0.50)
Expenditures '000 SLL	3504	26.529	3.019 *	11.575***	2.359
			(1.67)	(1.95)	(2.66)
Consumption Expenditure IHS Transformation					
Food Expenditures in the past week	3559	5.453	0.090	0.017	−0.042
			(0.06)	(0.09)	(0.13)
Expenditure on staples	3531	4.307	0.019	−0.343 **	0.254
			(0.10)	(0.16)	(0.21)
Expenditure on vegetables	3516	3.552	0.128**	0.281***	−0.079
			(0.06)	(0.07)	(0.11)
Expenditure on fish	3542	0.904	0.250**	−0.010	−0.075
			(0.11)	(0.10)	(0.14)
Expenditure on meat	3527	3.514	0.057	0.365***	−0.039
			(0.07)	(0.08)	(0.13)
Expenditure on fruit	3552	0.843	0.268**	−0.063	−0.101
			(0.10)	(0.10)	(0.14)
Expenditure on other foods	3504	3.626	0.163	0.345***	−0.101
			(0.10)	(0.10)	(0.14)
Food Security					
Ate less preferred food at least one day in the last week	3559	0.397	−0.010	−0.197***	0.007
			(0.04)	(0.03)	(0.05)
Reduced portion sizes for members of household	3559	0.342	−0.010	−0.180***	−0.022
			(0.04)	(0.03)	(0.04)
Asked relative or friend for help with food at least once in the past week	3559	0.274	−0.038	−0.175***	0.026
			(0.03)	(0.02)	(0.03)
Went one or more days with no meals in the past week	3549	0.130	−0.008	−0.098***	0.003
			(0.03)	(0.02)	(0.03)

Difference in Difference estimation uses electricity use from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects and clustered standard errors at the village level. The regression is weighted using Inverse Probability Weights.

5. Schools

This section describes the data collected from all Government and/or Government-Assisted schools in WP1 and WP2 communities. The data was collected in conjunction with the Baseline (2019), and Endline (2021) data collections for the academic school years 2018/2019, 2019/2020, and 2020/2021.

5.1 Data Collection

The school survey was administered to either the school Principal or the Head Teacher[25]. who had sufficient knowledge of the school and had access to all records. The survey instrument is included in Annex P. We collected data from all Government and/or Government-Assisted schools in both RREP and comparison sites, varying the number of schools per community and per wave of data collection[26]. This included information on the total number of students, disaggregated by gender and disability status, total number of teachers by gender, electricity access and all the national exam information for the NPSE, BECE and WASSACE.

5.1.1 Effects of Covid-19

The Covid-19 pandemic caused Sierra Leone to close in many different areas, the education system included. From April to July 2020 school going children were not allowed to be at school in person as per precautionary measures the government had put in place for the safety of everyone. This happened to be right before the national exams were supposed to be taken and were therefore postponed until further notice. The government then set a time for all of the students to take the exams, although at designated times to adhere to Covid-19 guidelines. These exams were then taken at the end of July/early August for all levels at the staggered schedule. Since the Endline data collection happened in late 2021, this meant the school records were accessible, though it should be noted that changes seen over time may have further implications due to the substantial break in schooling for students from Covid-19.

5.2 Exam Analysis

Table 23 reports the summary statistics for educational outcomes of the academic school years 2018/2019, 2019/2020, and 2020/2021 disaggregated by gender for WP1 communities followed by Table 24 for WP2 communities. At Baseline the disaggregation of disability status was not collected, and was quickly resolved from later data collections, which is shown in rows 4 and 5 and columns 6-10.

[25] If neither were available, the enumerator would find another teacher of that school who was able to provide all needed information including records.

[26] During the Baseline data collection, there were some communities that we did not collect any school information on. These data were then captured during the Endline data collection, except for the national exam records for the previous academic year.

5.2.1 Work package 1

On average, schools have increased attendance by about 10 students, the increase is driven by the amount of girls attending school being higher during the school year 2019/2020 than at the school year prior. Throughout the data collections the research team was able to locate more schools in the communities later on who enrolled more girls on average which could be a plausible reason for the increase of attendance. There is a small number of disabled students who attend the schools, on average 2 females with a maximum of 20 per school and 2 males with a maximum of 30 per school. Below the attendance, Table 23 reports the averages of national exam outcomes for all three school years for all schools. The national exams are restricted to certain grades in schools, and are conditional on those who took the exam. Over time it seems that on average the amount of students sitting the national exams, as well as those who are passing the exam slightly increases. More boys pass exams than girls (14.4 boys compared to 13.6 girls). An especially large increase over time can be observed for students passing the national senior secondary school exams (WASSCE), while we observe a drop in the number of students passing the junior secondary school exam (BECE).

Table 23: Summary Statistics: School Outcomes, WP1

	School year 2018/2019					School year 2019/2020					School year 2020/2021				
	N (1)	Mean (2)	Median (3)	Min (4)	Max (5)	N (6)	Mean (7)	Median (8)	Min (9)	Max (10)	N (11)	Mean (12)	Median (13)	Min (14)	Max (15)
Attendance															
Number of students attending	198	356.672	312	25	1885	201	366.468	329	45	1752	211	362.02	312	50	1700
Number of boys attend	198	188.005	163	19	1161	201	188.587	163	17	983	210	188.80	162	30	963
Number of girls attend	198	168.667	148	6	761	201	177.881	158	27	779	210	174.00	150	20	780
Number boy disabled students attend	0	.	.	.	.	201	2.836	2	0	30	211	3.56	2	0	36
Number girl disabled students attend	0	.	.	.	.	201	2.731	2	0	20	211	3.26	2	0	28
Exam Outcomes															
Number of students pass NPSE	127	28.031	21	0	140	136	28.037	25	0	157	141	31.85	27	0	162
Number of students pass BECE	63	48.968	35	0	230	62	61.339	56	0	224	61	66.08	58	1	224
Number of students pass WASSCE	25	14.840	0	0	250	28	8.071	2	0	58	24	15.33	0	0	219

This table shows summary statistics of school record data. Column (1) is the number of schools in the analytical sample. Column (2) is the mean number of students. Column (3) is the Median, and columns (4)-(5) are the minimum and maximum respectively.

5.2.2 Work package 2

Similar to WP1 communities, schools in WP2 have increased attendance by about 30 students over a three-year period. Here the increase is driven by both the amount of girls and boys attending school. There is a small number of disabled students who attend the schools, on average 3 females with a maximum of 47 per school and 3 males with a maximum of 52 per school. Below the attendance we can see that as in WP1 schools the average number of students sitting the national exams increases over time. A similar number of boys and girls pass the national exams each year. The average number of students passing the national senior secondary school exams (WASSCE) doubles from 2018/2019 to 2020/2021, however the number of observations is relatively small.

Table 24: Summary Statistics: School Outcomes, WP2

	School year 2018/2019					School year 2019/2020					School year 2020/2021				
	N (1)	Mean (2)	Median (3)	Min (4)	Max (5)	N (6)	Mean (7)	Median (8)	Min (9)	Max (10)	N (11)	Mean (12)	Median (13)	Min (14)	Max (15)
Attendance															
Number of students attending	521	373.33	319	25	1890	654	392.57	340	0	1952	335	403.23	356	0	1952
Number of boys attend	521	192.19	164	0	1320	653	198.82	168	0	1320	334	204.17	174	0	918
Number of girls attend	521	181.15	158	0	908	654	193.90	173	0	1057	335	199.37	183	0	1057
Number boy disabled students attend	0	.	.	.	.	335	3.19	2	0	52	335	3.19	2	0	52
Number girl disabled students attend	0	.	.	.	.	335	3.05	2	0	47	335	3.05	2	0	47
Exam Outcomes															
Number of students pass NPSE	322	27.98	23	0	140	386	31.22	27	0	140	189	36.92	32	0	168
Number of students pass BECE	155	54.49	39	0	368	182	63.32	43	0	339	91	81.74	63	0	407
Number of students pass WASSCE	61	14.20	0	0	250	76	52.09	1	0	1060	28	30.14	0	0	700

This table shows summary statistics of school record data. Column (1) is the number of schools in the analytical sample. Column (2) is the mean number of students. Column (3) is the Median, and columns (4)-(5) are the minimum and maximum respectively.

Tables 25 and 26 below report the difference-in-difference estimation on all the Government and/or Government-Assisted schools for WP1 and WP2.

5.2.3 Work package 1

Column 5 in Table 25 shows that no significant treatment effects of the RREP intervention over time can be found. Column 3 suggests that the average number of students is initially higher in RREP communities, however, this difference is not significant and decreases over time. Similar dynamics can be observed for the number of boys and girls attending schools. The only significant differences we can find are for the national exam outcomes. However, also here, no significant treatment effect can be found. RREP communities have significantly more students attending the primary national exams in 2019 as well as in 2021 (row 6). Moreover, significantly more students in RREP communities pass the primary school exams or the junior secondary school exams in 2021 (row 7 and 10, column 4), but the difference between RREP and comparison schools decreases over time and loses all significance. With the underlying data, it appears that the RREP project has no effect on educational outcomes. More information is necessary to draw definite conclusions.

Table 25: Difference-in-Difference School Outcomes, WP1

	N (1)	Mean in Control in 2019 (2)	RREP vs Non RREP in 2019 (3)	Post (4)	Post x RREP (5)
Attendance					
Number of students attending	189	349.471	12.974	5.851	-2.539
			(44.267)	(12.868)	(18.14)
Number of boys attend	188	183.042	7.87	2.416	-0.458
			(24.353)	(7.35)	(9.71)
Number of girls attend	188	166.179	5.066	8.122	2.726
			(20.542)	(6.93)	(10.05)
Exam Outcomes					
Number of students pass NPSE	124	23.757	6.202	4.836*	-0.189
			(5.132)	(2.78)	(3.98)
Number of students pass BECE	56	66.362	-20.592	14.812*	-2.008
			(19.379)	(7.59)	(9.23)
Number of students pass WASSCE	23	58.93	-61.131	-11	-17.845
			(46.884)	(64.67)	(64.85)

Difference in Difference estimation uses school data from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects and clustered standard errors at the village level.

*This table shows the Difference-in-Differences in educational outcomes between Work package 1 treatment and comparison communities pre-and post-RREP project. The pre-RREP measures are from the 2018/2019 records, and the post-RREP measures use 2020/2021 records. Column 1 shows the number of observations per outcome. Column 2 shows the mean value of each outcome in the control group during 2018/2019. Column 3 reports the mean difference between control and treatment communities at baseline. Column 4 shows the mean difference in outcomes from pre- to post-RREP periods for control group. Column 5 shows DID estimates from a regression estimated where the change in an outcome (post-pre-RREP) is regressed on a treatment indicator with district fixed effects and standard errors clustered at the community level. Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01. Data source: School records.*

5.2.4 Work package 2

Similar to WP1 communities, the WP2 communities observe no significant difference from the school years 2018/2019 to 2020/2021 for the RREP project on educational outcomes. It seems as though there are some initial differences when looking at the treatment variables in Column 3 between RREP school and comparison schools during Endline for most of the variables (Column 4), however, all variables loose significance over time and expresses the same conclusion that electrification has yet to create an impact on educational outcomes.

Table 26: Difference-in-Difference School Outcomes, WP2

	N (1)	Mean in Control in 2019 (2)	RREP vs Non RREP in 2019 (3)	Post (4)	Post x RREP (5)
Attendance					
Number of students attending	323	327.902	78.396***	29.534**	-7.91
			(24.167)	(11.997)	(17.378)
Number of boys attend	322	165.404	40.609***	20.312***	-12.075
			(13.092)	(7.502)	(9.861)
Number of girls attend	323	162.475	37.804***	9.241	4.717
			(12.783)	(6.561)	(11.038)
Exam Outcomes					
Number of students pass NPSE	188	20.701	11.201***	12.423***	-4.459
			(3.32)	(2.408)	(3.713)
Number of students pass BECE	89	42.666	19.518**	24.740**	0.931
			(9.08)	(9.602)	(13.179)
Number of students pass WASSCE	31	5.345	9.445	19.49	-1.067
			(14.116)	(17.791)	(16.274)

Difference in Difference estimation uses school data from 2019 as the pre period and from 2021 as the post period. Includes district fixed effects and clustered standard errors at the village level.

*This table shows the Difference-in-Differences in educational outcomes between Work package 2 treatment and comparison communities pre-and post-RREP project. The pre-RREP measures are from the 2018/2019 records, and the post-RREP measures use 2020/2021 records. Column 1 shows the number of observations per outcome. Column 2 shows the mean value of each outcome in the control group during 2018/2019. Column 3 reports the mean difference between control and treatment communities at baseline. Column 4 shows the mean difference in outcomes from pre- to post-RREP periods for control group. Column 5 shows DID estimates from a regression estimated where the change in an outcome (post-pre-RREP) is regressed on a treatment indicator with district fixed effects and standard errors clustered at the community level. Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01. Data source: School records.*

6. Community Health Clinics

This section presents a summary of data collected from CHCs in WP1 and WP2 communities. These data were collected between the duration of the Baseline and Endline data collections for two different sources of information on the clinic qualities and many of the health registers for the years of 2016, 2018, 2019, 2020 and 2021.

6.1 Data Collection

We have collected data on the clinics from two sources: interviews with the Community Health Officer (CHO)[27] of the clinic, and data from the standardized health registers on which each CHC keeps records.

The CHO surveys were conducted at Baseline (2019), and Endline (2021), during the same data collection period as the household and school surveys covered above. In these surveys, the respondents are asked about CHC operations, conditions, capacities, and equipment. The survey instrument is included in Annex I. While the CHO survey was administered, five health registers were collected to be able to assess the full utilization of the clinic and compare across RREP and non-RREP sites.

6.2 CHC Electrification Timeline

The majority of community health clinics in our sample were electrified in 2017 to enable Ebola containment efforts. Since then, the RREP has electrified every CHC in the WP1 RREP communities. Of the 54 RREP clinics in Work Package 1, 50 were electrified between April and October 2017, and 4 were electrified in early 2018[28]. By identifying the date of electrification, we can analyze conditions prior to and following that date. Of the 55 comparison clinics in Work Package 1, 18 had access to electricity at Baseline increasing to 34 during Endline two years later. The large majority of comparison clinics with energy access use stand-alone solar panels as an energy source.

The electrification of Work Package 2 RREP communities started in 2021, but was not completed at the time of the Endline data collection. At Endline around 61 percent (25) of 42 RREP clinics in WP2 have been electrified through mini-grid access. At the same time, around 62.8 percent (27) of 43 comparison CHC's have access to electricity in WP2, generally through stand-alone solar panels.

We have collected register data for the entirety of 2016, 2018, 2019, 2020, and the first ten months of 2021. The 2016 data was only collected for WP1 and provide a baseline, which describes the state of the CHCs prior to electrification. This baseline can then be compared to the register data collected for years after 2018, and differential changes between the RREP and comparison

[27] Or other in-charge if the clinic has no CHO or the CHO is not present.
[28] UNOPS — RREP Results Matrix

villages are identified. For WP2 CHCs the 2018 data provide a baseline to conduct the analysis as the electrification status was at a later date. This difference-in-differences methodology mirrors what was used to analyze the household data, and is described in Section 3.7.

Electrification may be a necessary but not sufficient condition to bring about the positive changes we seek. If not accompanied by other investments in infrastructure, productive appliances, training and incentives for clinic staff, or proper materials, electrification may be used for nothing more than phone charging and light at night. If electricity access is the only infrastructure that improves, outcomes may remain stagnant due to lack of investment in needed areas.

6.3 Monthly Register Data

For each clinic-month for WP1 clinics, we collected data stored in a number of documents for the years of 2016, 2018, 2019, 2020 and 2021 totalling to 58 months, though for WP2 we only collected from the years 2018 and onwards. The records captured during these years were among the following:

- Above five year old treatment register
- Under five year old treatment register
- Under two year old EPI register
- Family planning register
- Mother and neonate register
- Vaccination register

Many clinics do not consistently have access to their older monthly registers. For example, while all but five clinics in our sample provided their mother and neonate register for May 2021, 101 clinics (about half) were unable to provide that register for April 2018. A similar pattern exists for all of the register types. This is often due to the paper records degrading over time, getting lost, or being discarded.

6.3.1 Effects of Covid-19

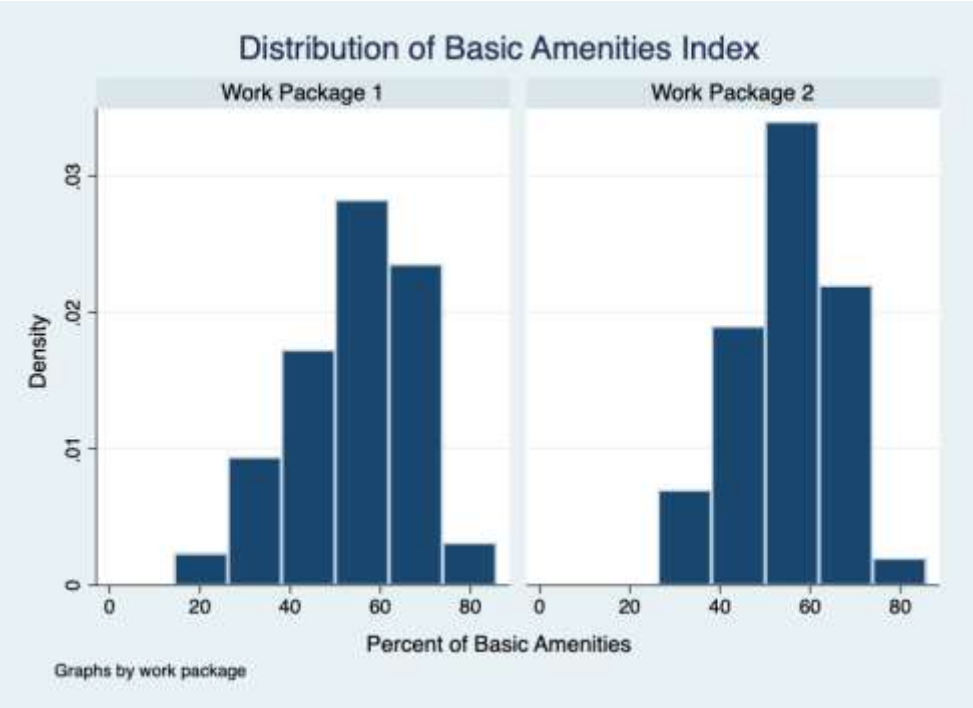
The effects of the Covid-19 pandemic are visible in the CHC data. All CHCs were electrified at least two years prior to the first reported cases of Covid-19 in Sierra Leone; therefore the effects of the pandemic are visible throughout all clinics and months following electrification.

With the onset of Covid-19, we expect changes in how many people visit the CHCs. Covid-19 effects on CHC utilization are not straightforward. First, as more community members become sick or worry that they might become sick, they may seek medical treatment at the clinics. We expect this effect would increase the rate of CHC utilization. Second, individuals who are concerned about catching Covid-19 may postpone or avoid treatment at clinics, in the worries of becoming infected there similar to when Ebola hit Sierra Leone. We expect this would depress the rate of CHC utilization during the Covid-19 crisis.

6.4 Clinic Type and Quality

In order to accurately measure the effects of electrification on the CHCs, it is critical to look at and measure the clinic quality. There is significant heterogeneity in clinic quality across the sample that may inform the impact of electricity on that clinic. It is reasonable to assume that a lower quality clinic will experience more benefits from electrification than a higher quality clinic that receives electricity. In order to understand the quality of the clinic's, the service availability and readiness assessment (SARA)[29] was used to generate questions related to basic aspects of health clinics. These measures were developed by the World Health Organization and the United States Agency for International Development (USAID). The indicators used were the general service readiness indicators that consist of the following measures: basic amenities, basic equipment, standard precautions for infection prevention, diagnostic capacity, and essential medicines. The indicator for each category ranges from 0 to 100 with the score representing the percentage of items in that category that a clinic has. The specific questions in each indicator are described below, along with histograms of the values for communities, separated by work package (Figures 2 to 6). Across the work packages the histograms look largely similar.

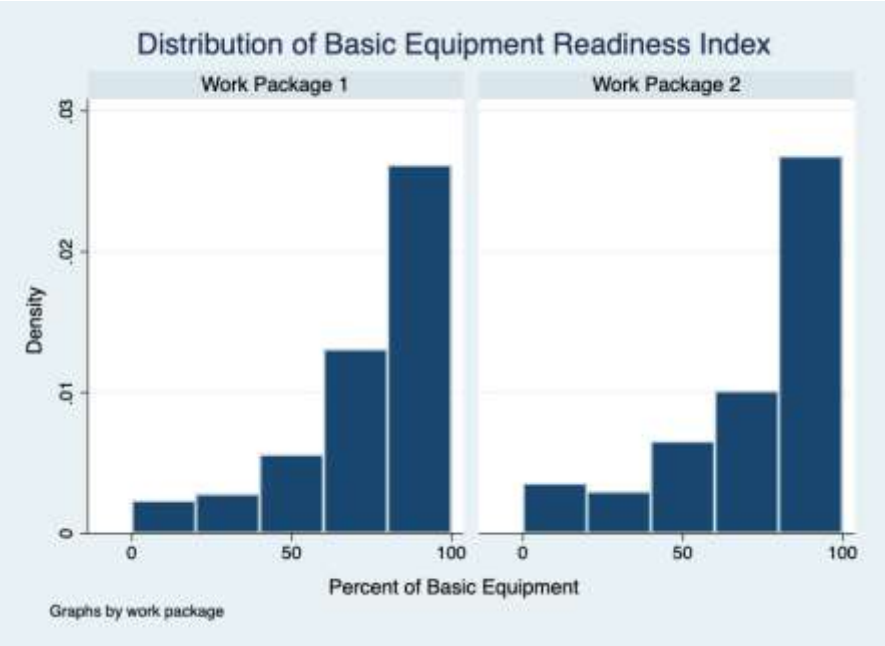
Figure 2: Histogram of Basic Amenities Index by WP



Note: The basic Amenities index includes: power, improved water source inside or within the ground of the facility, room with auditory and visual privacy, access to adequate sanitation facilities, communication equipment, access to a computer with email/internet access, and emergency transportation

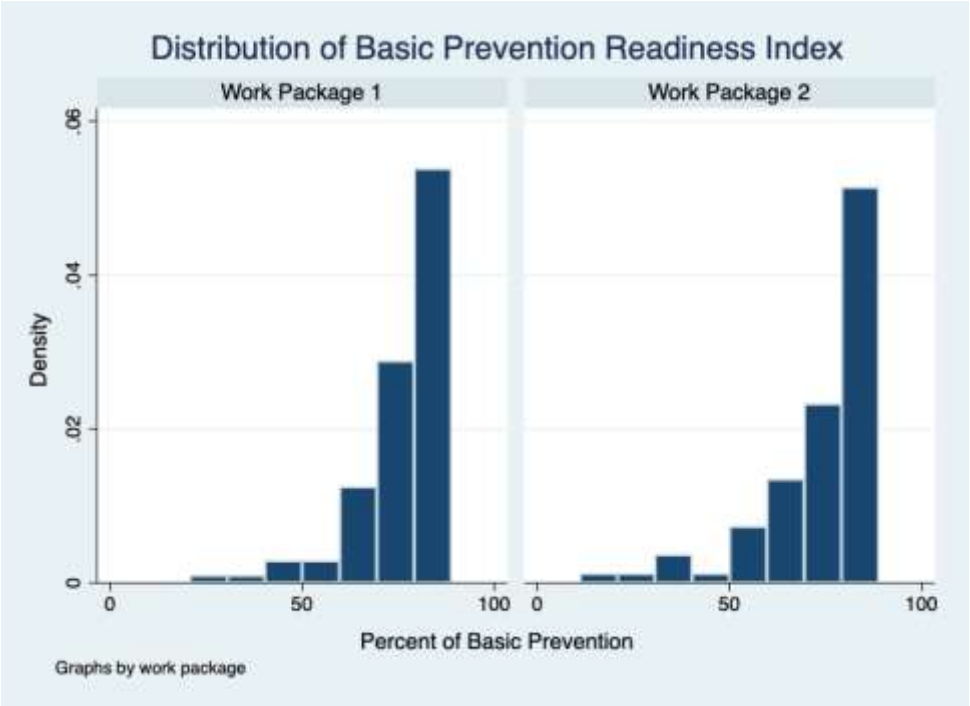
[29] https://www.who.int/data/data-collection-tools/service-availability-and-readiness-assessment-(sara)?ua=1

Figure 3: Histogram of Basic Equipment Index by WP



Note: Basic equipment index includes: adult scale, child scale, thermometer, stethoscope, blood pressure apparatus, light source

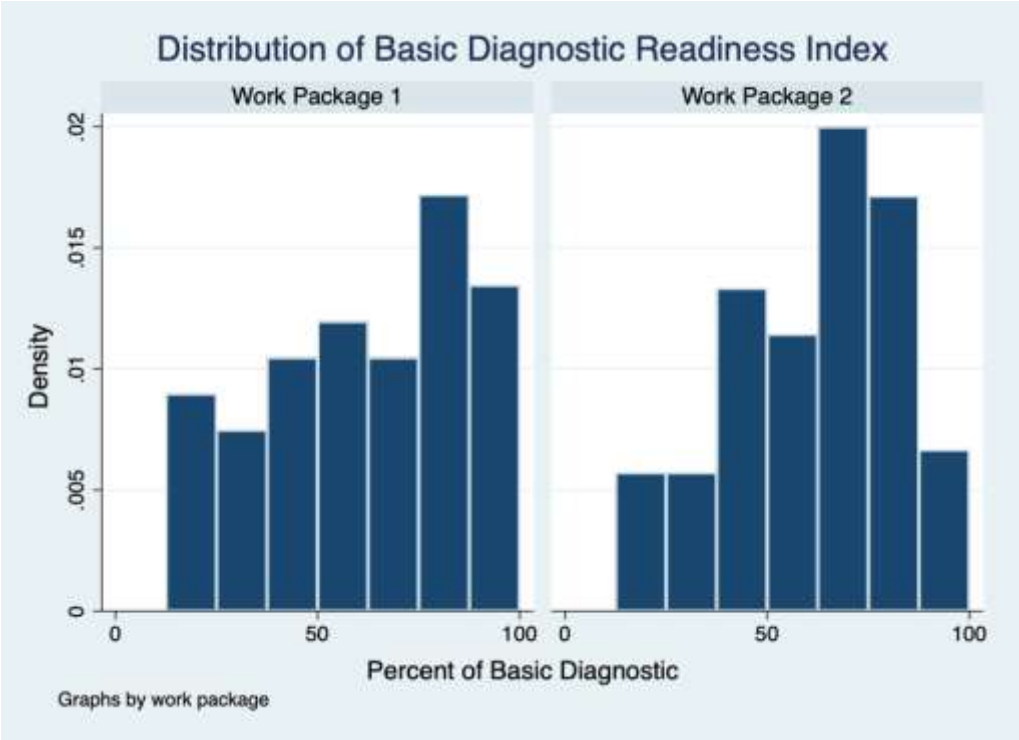
Figure 4: Histogram of Basic Prevention Index by WP



Note: Standard precautions for infection prevention index includes: safe final disposal of sharps, safe final disposal of infectious wastes, appropriate storage of sharps waste, appropriate storage of infectious waste,

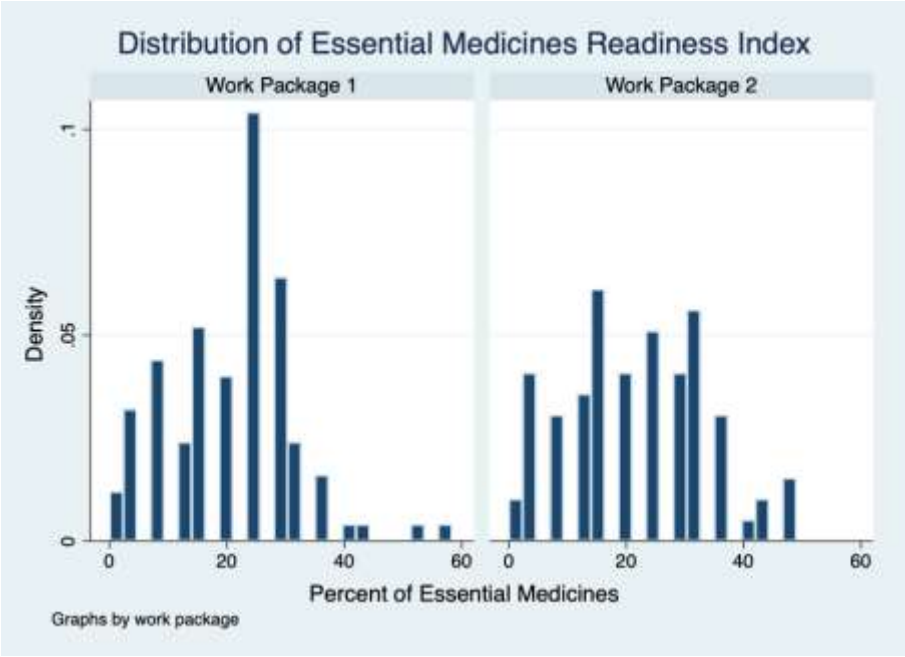
disinfectant, single use or auto-disable syringes, soap and running water or alcohol based hand rub, latex gloves, guidelines for standard precautions

Figure 5: Histogram of Basic Diagnostic Index by WP



Note: Diagnostic capacity index include: haemoglobin, blood glucose, malaria diagnostic capacity, urine dipstick - protein, urine dipstick - glucose, HIV diagnostic capacity, Syphilis rapid test, urine test for pregnancy

Figure 6: Histogram of Essential Medicines Index by WP



Note: Essential medicines index includes: amlodipine table (or alternative calcium channel blocker), amoxicillin syrup/suspension or dispersible table, amoxicillin tablet, ampicillin powder for injection, aspirin cap/tab, beclometasone inhaler, beta blocker (e.g. bisoprolol, metoprolol, carvedilol, atenolol), carbamazepine tablet, ceftriaxone injection, diazepam injection, enalapril tablet (or alternative ACE inhibitor), fluoxetine tablet, gentamicin injection, glibenclamide tablet, haloperidol tablet, insulin regular injection, magnesium sulphate injectable, metformin tablet, omeprazole tablet (or alternative such as pantoprazole, rabeprazole), oral rehydration solution, oxytocin injection, salbutamol inhaler, simvastatin tablet or other statin (e.g. atorvastatin, pravastatin, fluvastatin), thiazide (e.g. hydrochlorothiazide), zinc sulphate tablets (or syrup)

In order to better understand the distribution of each indicator, summary statistics were calculated. The data was first subsetted by the work package, first displaying WP1 and then for WP2. Additionally, the data was subsetted by access to electricity as well as being either an RREP community or a comparison site.

Table 27: Summary Statistics for WP1 by RREP Assignment

WP 1 Summary statistics:
Non-RREP sites

	Mean	Min	p25	Median	p75	Max	SD
Basic amenities	45.238	14.286	28.571	42.857	57.143	71.429	15.136
Basic equipment	66.667	0	50.000	66.667	83.333	100	25.287
Basic prevention	79.012	22.222	77.778	88.889	88.889	88.889	15.812
Basic diagnostic	47.917	12.5	25.000	50	62.5	100	24.971
Essential medicines	20.074	0	12.000	22	24	56	10.611
RREP sites							
Basic amenities	64.69	42.857	57.143	71.429	71.429	85.714	11.067
Basic equipment	82.39	33.333	66.667	83.333	100	100	20.259
Basic prevention	80.503	55.556	77.778	77.778	88.889	88.889	9.475
Basic diagnostic	64.151	12.5	50.000	75	87.5	100	24.396
Essential medicines	21.057	0	12.000	24	28	52	10.76

For WP1 communities, we see that CHCs in RREP sites have higher values for each of the indices on average, this suggests that clinic quality is correlated with having access to electricity. This effect is also seen when we compare CHCs with electricity access to those without below.

Table 28: Summary Statistics for WP1 by Electrification Status

WP 1 Summary statistics:
CHC has access to electricity: No

	Mean	Min	p25	Median	p75	Max	SD
Basic amenities	37.143	14.286	28.571	42.857	42.857	57.143	12.608
Basic equipment	55	16.667	33.333	58.333	66.667	100	26.546
Basic prevention	76.667	22.222	72.222	88.889	88.889	88.889	19.38
Basic diagnostic	41.25	12.5	18.750	37.5	62.5	75	22.977
Essential medicines	18.2	0	10.000	18	24	36	10.258
CHC has access to electricity: Yes							
Basic amenities	58.949	14.286	57.143	57.143	71.429	85.714	14.419
Basic equipment	78.927	0	66.667	83.333	100	100	21.335
Basic prevention	80.46	44.444	77.778	88.889	88.889	88.889	11.107
Basic diagnostic	59.339	12.5	37.500	62.5	75	100	25.448
Essential medicines	21.103	0	16.000	24	28	56	10.717

Table 29: Summary Statistics for WP2 by RREP Assignment

WP 2 Summary statistics:
Non-RREP sites

	Mean	Min	p25	Median	p75	Max	SD
Basic amenities	54.817	28.571	42.857	57.143	71.429	71.429	13.917
Basic equipment	69.767	0	50.000	83.333	100	100	28.465
Basic prevention	73.643	11.111	66.667	77.778	88.889	88.889	19.85
Basic diagnostic	52.035	12.5	37.500	50	75	87.5	21.81
Essential medicines	19.535	0	12.000	20	28	48	10.698
RREP sites							
Basic amenities	57.143	28.571	42.857	57.143	71.429	85.714	13.553
Basic equipment	76.016	16.667	66.667	83.333	100	100	23.288
Basic prevention	80.217	33.333	77.778	88.889	88.889	88.889	12.793
Basic diagnostic	59.146	12.5	50.000	62.5	75	100	21.474
Essential medicines	23.902	0	12.000	24	32	48	12.853

The WP2 communities described in the summary statistics below are disaggregated by the clinics who have electricity access and by those who do not.

Table 30: Summary Statistics for WP2 by Electrification Status

WP 2 Summary statistics:
CHC has access to electricity: No

	Mean	Min	p25	Median	p75	Max	SD
Basic amenities	46.429	28.571	42.857	42.857	57.143	57.143	10.886
Basic equipment	63.021	0	50.000	66.667	83.333	100	26.005
Basic prevention	78.819	11.111	77.778	88.889	88.889	88.889	18.15
Basic diagnostic	57.812	12.5	37.500	62.5	75	100	19.247
Essential medicines	22.625	0	14.000	24	32	48	11.7
CHC has access to electricity: Yes							
Basic amenities	61.813	28.571	57.143	57.143	71.429	85.714	11.909
Basic equipment	78.846	16.667	66.667	83.333	100	100	24.503
Basic prevention	75.641	22.222	66.667	77.778	88.889	88.889	16.324
Basic diagnostic	54.087	12.5	37.500	62.5	75	100	23.316
Essential medicines	21.077	0	12.000	20	30	48	12.146

6.5 Electricity Use

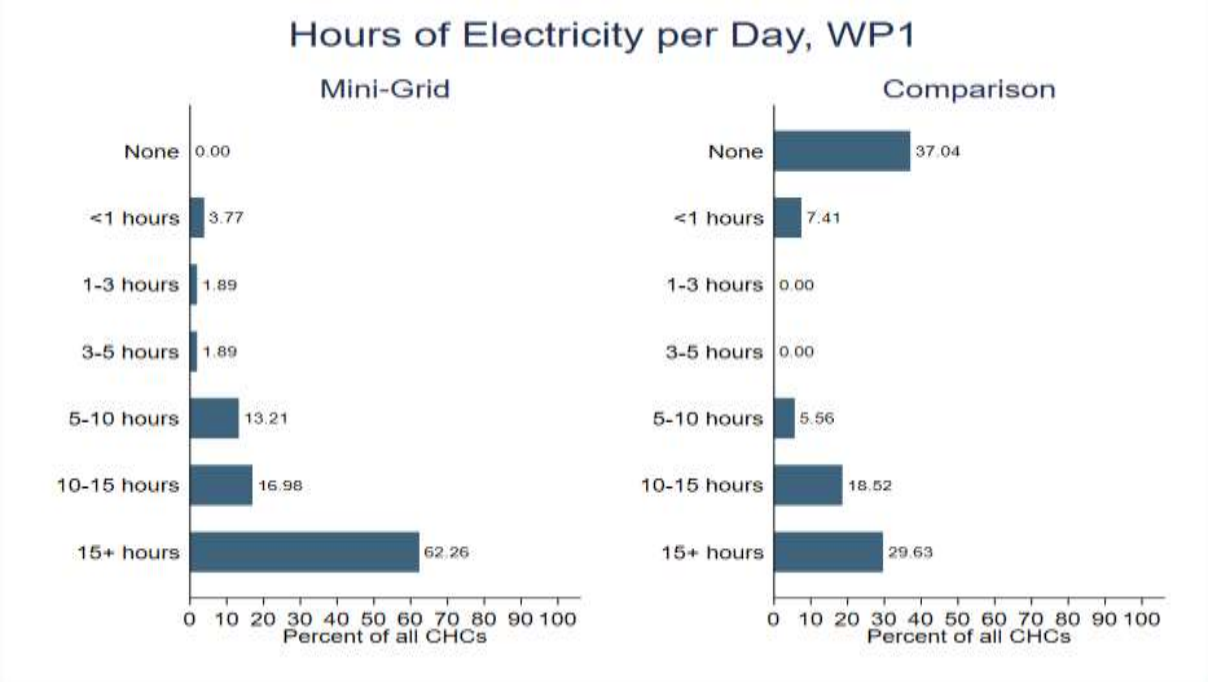
At Baseline and Endline, the CHO survey instrument collected data on electricity use and electrified assets in the clinics. These assets included patient care devices, such as oxygen plants and automatic external defibrillators, assets for cleaning, such as sterilizers, and storage equipment, such as refrigerators and freezers. Unlike the households in the comparison communities, comparison CHCs are relatively likely to have access to electricity due to NGOs or other organizations donating solar freezers or other items, according to KIIs. Overall, 62.9 percent of comparison CHCs in both WPs have access to electricity; of these, 86.9 percent use a stand-

alone solar panel system. Throughout the rest of this section when moving to the analysis, the results will be reported for WP1 and WP2 communities separately due to the differences in electrification status and overall baseline differences of the communities.

6.5.1 Work Package 1

Figure 7 below displays the number of hours of electricity the CHC has during the day between RREP clinics and comparison clinics. Among RREP CHCs, around 79 percent have at least 10 hours of electricity per day. Among comparison CHCs, just 48.15 percent have light for so many hours per day. About 37 percent of RREP clinics have less than 15 hours of light per day, whereas a substantial percentage of comparison clinics have absolutely no light, 37.04 percent.

Figure 7: Electricity Hours in WP1 CHCs by RREP Status at Endline

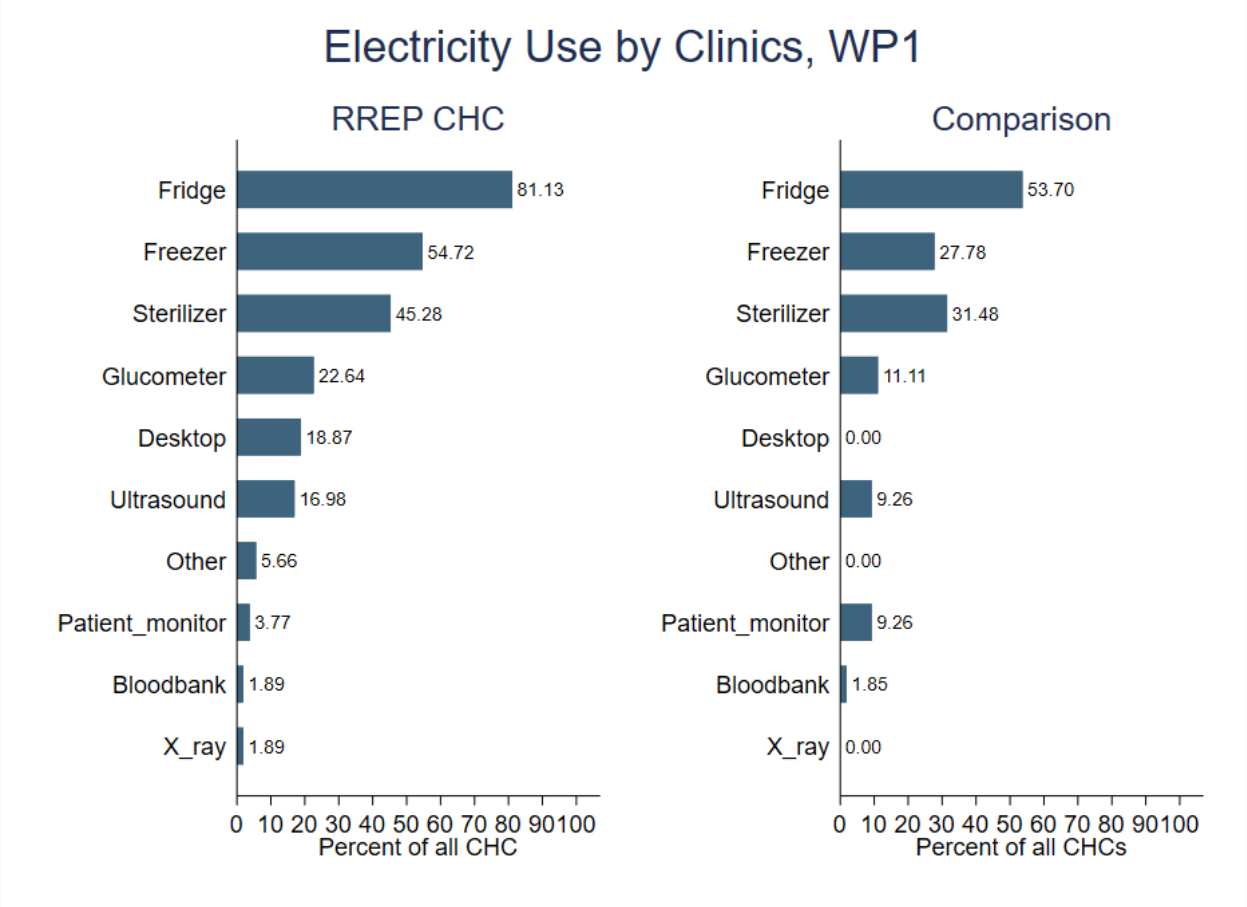


In Figure 8 below, we focus on the Endline survey results of electric asset use, by RREP status. For many assets, the RREP communities have higher rates of ownership. Notably, RREP communities are substantially more likely than comparison communities to own refrigerators (81.1 percent, compared to 53.7 percent), freezers (54.7 percent, compared to 27.8 percent), and sterilizers (45.3 percent, compared to 31.5 percent).

This may be explained by how CHCs prioritize the equipment they purchase, and how much electricity a particular piece of equipment requires to operate. When a CHC gains access to consistent electricity (through a mini-grid, for example), they may prefer to purchase and operate a freezer rather than a blood pressure machine. Additionally, of the communities in the comparison community which have access to electricity (63 percent) around 88 percent use a

stand-alone solar panel system. While this system may be enough to operate a blood pressure machine, it provides insufficient power to operate a refrigerator or freezer consistently.

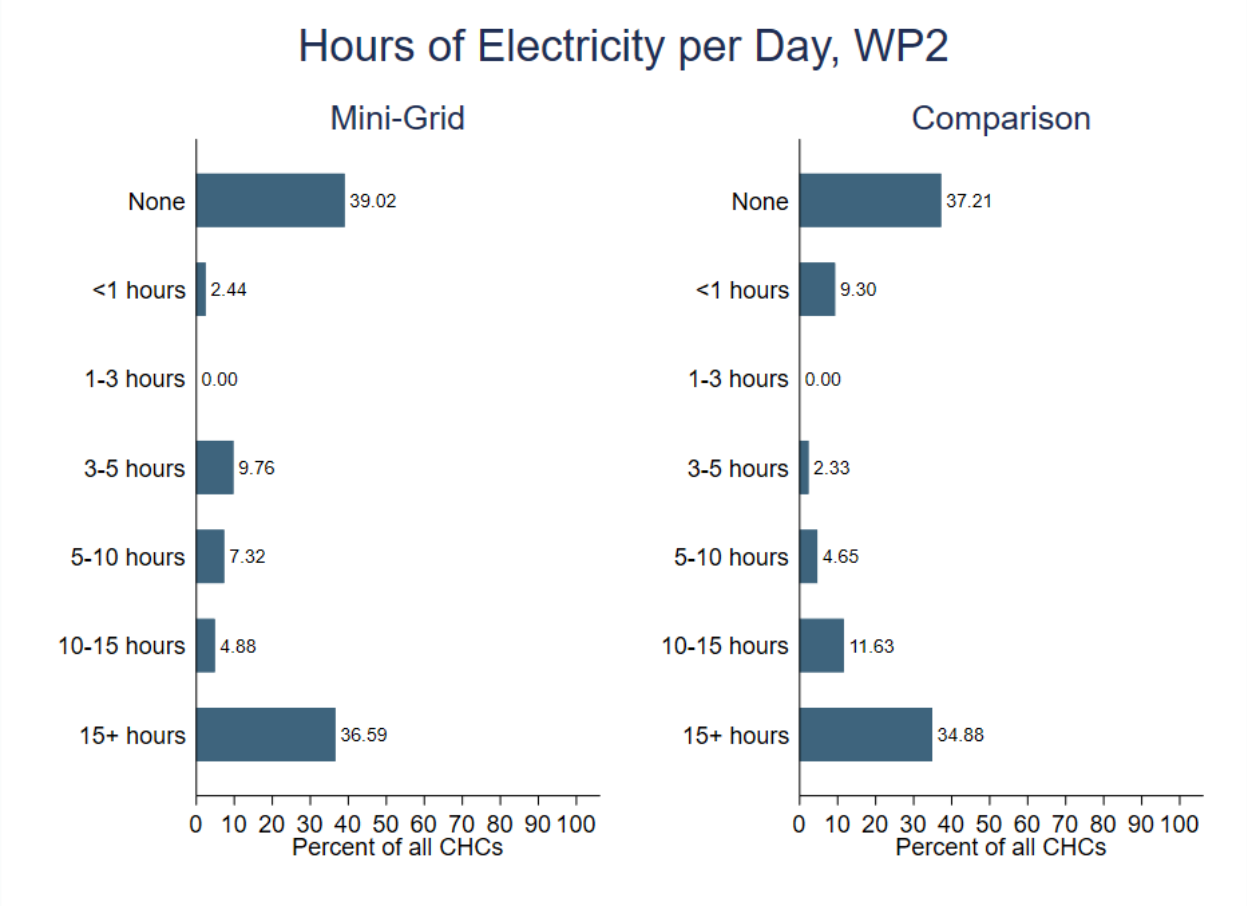
Figure 8: Electricity Usage by WP1 CHCs by RREP Status at Endline



6.5.2 Work Package 2

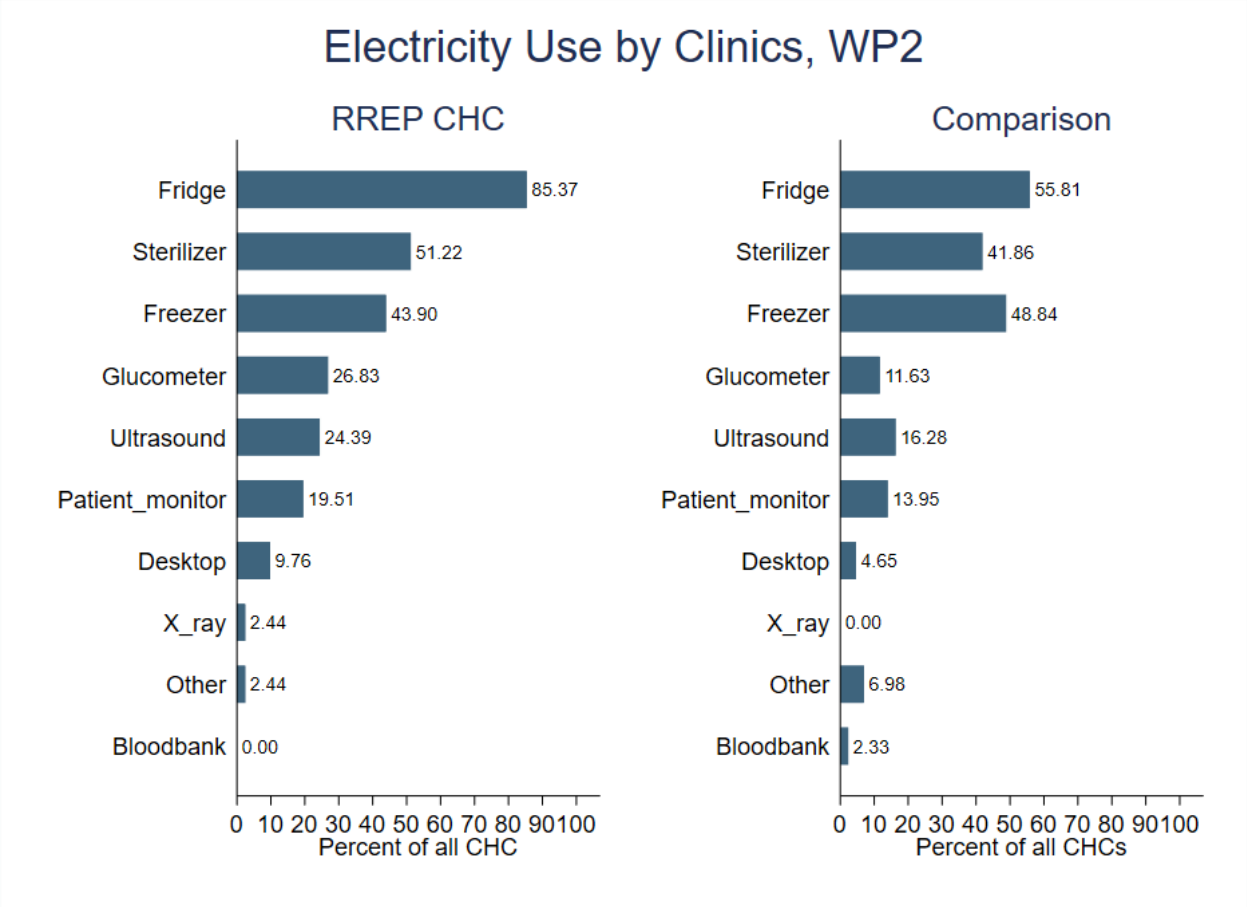
Looking at the number of hours of electricity per day in WP2 CHCs in Figure 9, we notice that in comparison to WP1 smaller differences exist between RREP and comparison clinics. This dynamic is mostly driven by the fact that only around 61 percent of all WP2 communities had been electrified at the time the survey was conducted. Among RREP CHCs, around 41 percent have at least 10 hours of electricity per day. Surprisingly, more comparison CHCs (46.5 percent) have light for so many hours per day. About 41.5 percent of RREP clinics have no or less than one hour of light per day, whereas the mean difference for comparison clinics is only five percent higher, 46.5 percent. Around 62.8 percent of comparison CHCs in WP2 have access to electricity, 85 percent of those use a stand-alone solar panel system.

Figure 9: Electricity Hours in WP2 CHCs by RREP Status at Endline



Similar to WP1, RREP communities in WP2 have higher rates of electric asset ownership. Even though differences between treatment and comparison communities are of smaller magnitude than in WP1, they are still significant. Notably, RREP communities are substantially more likely than comparison communities to own refrigerators (85.4 percent, compared to 55.8 percent) and sterilizers (51.2 percent, compared to 41.8 percent). Surprisingly, relatively more comparison communities own a freezer than RREP communities (48.8 percent compared to 43.9 percent).

Figure 10: Electricity Usage by WP2 CHCs by RREP Status at Endline



6.6 Register Analysis

The monthly data were averaged into quarters per year. Each tick in the figures represents a three month time period, the first tick is January, February and March in 2016 averaged together to get the total patient visits. The next data point averages April, May and June 2016, and so on until October 2021.

Figure 13, and all following figures of the registers, shows a regression estimate between RREP communities (the red line in all figures) and the comparison communities (the blue line). This regression tests for statistically significant differences between the utilization of electrified and non-electrified CHCs. The confidence intervals are displayed for both types of communities indicating if there was any significant change that occurred over the time period when electrification (the solar mini-grids were placed) interacted with time in the communities. Due to more 2016 data being missing, the confidence intervals for that year are quite large, indicating substantial uncertainty. This is not necessarily an indication that CHCs are struggling, but rather

that more information will be needed before we can provide more definite conclusions as to how electrification impacts clinic utilization. The dashed line separates out the year 2016 and 2018 because all CHCs were electrified after the year 2016. As stated earlier, no data for the year 2016 was collected for WP2 communities.

6.6.1 Above Five New Patients

Figures 13 and 14 present the monthly register data for the Above Five Total New Patients and the disaggregation between female and male new patients for WP1 and WP2 respectively. A new patient is classified as a person coming into the clinic for the first time for a new symptom. A patient visiting one week for a fever, and the next week for a broken foot, would be classified as two separate new patients.

6.6.1.1 Work Package 1

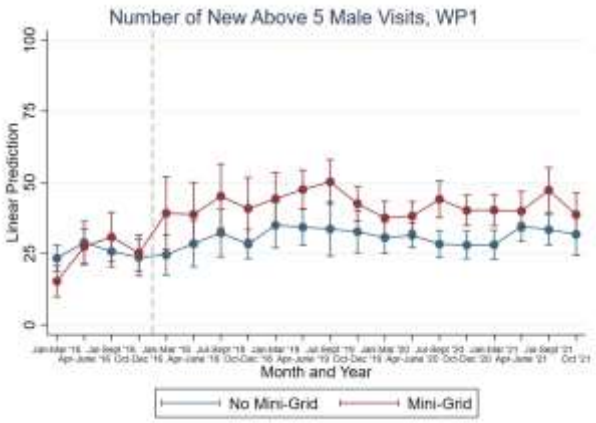
Figure 13 indicates that RREP communities have higher utilization, though this finding is not statistically significant. We also see comparison CHCs begin to catch up with RREP clinics in 2020 and 2021. Women are more likely to go to a CHC as a new patient than men are, though the difference is not substantial. Surprisingly, regression results indicate that RREP clinics are significantly less likely to admit male patients above 5 (p=0.027) compared to comparison clinics, however, this treatment effect might be mainly driven by the increasing utilization rates of comparison clinics and could be largely due to Sierra Leone giving free health care to pregnant women and children under 5. This could be seen as a deterrent for men to seek aid from the clinics and is highly likely the underlying reason why the clinics are seeing many fewer men than women. Standard errors remain large and confidence intervals close to zero, therefore more data is needed to establish definite conclusions.

Figure 13: Above 5 Total New Patients, Female New Patients and Male New Patients, WP1

Above 5 New Patients Female

Above 5 New Patients

Above 5 New Patients Male



6.6.1.2 Work Package 2

As no register data for 2016 was collected for WP2 CHC's, Figure 14 shows the monthly register data for the Above Five New Patients from 2018 onwards in three month intervals. For certain months Figure 14 indicates higher utilization rates for RREP communities, however confidence intervals displayed by the vertical whiskers show no statistical significant difference. This is in line with earlier findings for WP2 communities, as a substantial part of WP2 communities have not been electrified yet. Similar to WP1, women seem to be more likely to go to a CHC as a new patient than men.

Figure 14: Above 5 Total New Patients, Female New Patients and Male New Patients, WP2

Above 5 New Patients

Above 5 New Patients Female

Above 5 New Patients Male

6.6.2 Above Five Follow-Up Patients

Figures 15 and 16 below displays the regression estimate for follow-up visits by above-five patients. A follow-up patient is classified as someone who came to the clinic once again for the exact same reason as they previously came to the clinic for. A patient who visits once for their broken foot is counted as a new patient. Their second and all subsequent visits for the broken foot are classified as follow-up visits.

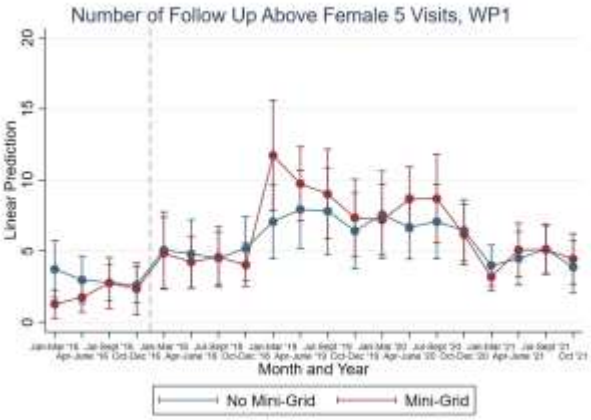
6.6.2.1 Work Package 1

The trends of follow-up patient visits in RREP and comparison clinics, shown in Figure 15, generally follow a common trend with largely overlapping confidence intervals. However, according to our regression results RREP CHCs are significantly less likely to admit female(p=0.032), male (p=0.045) and all (p=0.04) follow-up patients above five years old. As seen earlier for new patients above five, standard errors remain large and confidence intervals close to zero, therefore more data is needed to establish definite conclusions. Treatment effects might be driven by improving comparison CHCs rather than worsening RREP CHCs.

Figure 15: Above 5 Total Follow-Up Patients, Female Follow-Up Patients and Male Follow-Up Patients, WP1

Above 5 Follow-Up Patients

Above 5 Follow-Up Patients Female



Above 5 Follow-Up Patients Male

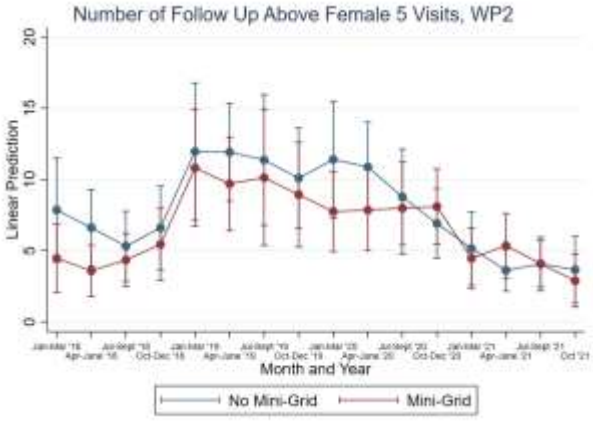
6.6.2.2 Work Package 2

Similar to WP1, we can see in Figure 9 that trends of follow-up patient visits for both groups in WP2 follow a common trend and do not show any significant differences. We can observe a decline in the number of follow-up visits mid 2019 onwards. WP2 data appears noisier with larger confidence intervals than WP1 data, most likely due to a smaller number of observations.

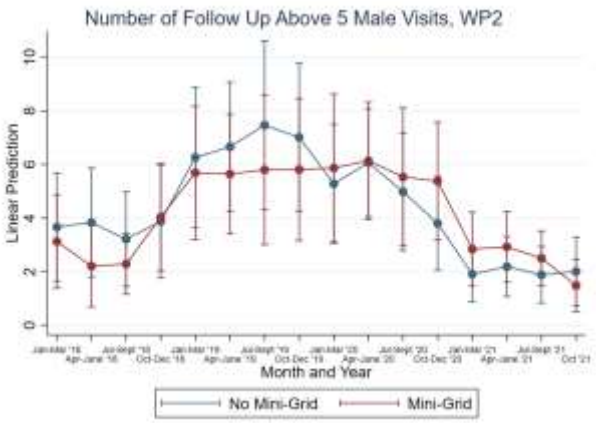
Figure 16: Above 5 Total Follow-Up Patients, Female Follow-Up Patients and Male Follow-Up Patients, WP2

Above 5 Follow-Up Patients

Above 5 Follow-Up Patients Female



Above 5 Follow-Up Patients Male



6.6.3 Under Five New Patients

Figures 17 and 18 below report the regression estimates for Under 5 Total New Patients over time.

6.6.3.1 Work Package 1

In Figure 17 we can see that the data for under 5 patients for the year 2016 are noisier than the other years, due to missing observations. As with adults, the RREP clinics have higher clinic utilization across all time periods, though the gap narrows substantially from 2018 throughout 2020. We find statistically significant differences for the total number of new patients under five (p=0.02) and new male patients under five (p=0.00), indicating that RREP CHCs are significantly more likely to admit new patients under five than comparison clinics. The first first treatment effect might be driven by the later, however it is surprising that no treatment effect can be found for new female patients under five. Therefore, more information is necessary to draw definite conclusions.

Figure 17: Under 5 Total New Patients, Female New Patients and Male New Patients, WP1

Under 5 New Patients

Under 5 New Patients Female

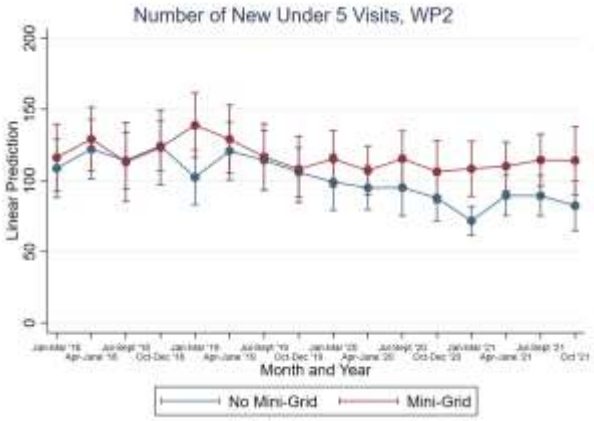
Under 5 New Patients Male

6.6.3.2 Work Package 2

Figure 18 displays the register data for Under 5 Total New Patients over time in WP2. We can see that RREP and comparison clinics have initially similar levels and trends of under five patient visits. From October 2019 onwards it seems that comparison CHCs have declining patient visits, while RREP patient numbers remain relatively constant. Nonetheless, we find no significant differences between both groups and confidence intervals tend to overlap.

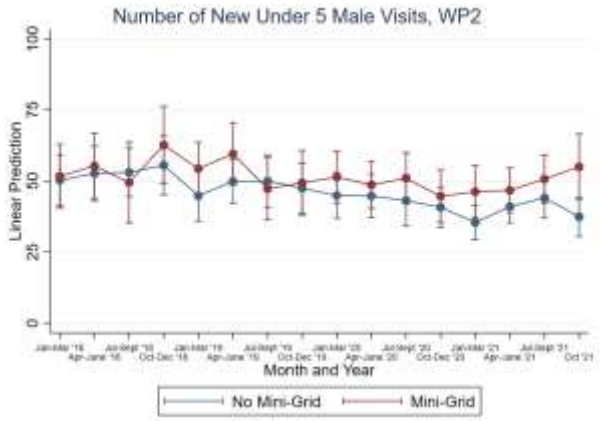
Figure 18: Under 5 Total New Patients, Female New Patients and Male New Patients, WP2

Under 5 New Patients



Under 5 New Patients Female

Under 5 New Patients Male



6.6.4 Family Planning Patients

In Figures 19 and 20 below, we show a regression on data from the Family Planning register. The family planning is taken by total patients, then disaggregated by female and male patients.

6.6.4.1 Work Package 1

As with all previous figures, the RREP clinics are having more utilization throughout the timeline, though no statistically significant differences can be found. Confidence intervals are especially large for observations in 2016, with relatively constant patient numbers after.

Figure 19: Total Family Planning Visits, Female Family Planning Visits and Family Planning Visits, WP1

Total Family Planning Patients

Female Family Planning Patients

Male Family Planning Patients

6.6.4.2 Work Package 2

In Figure 20 below we see that RREP clinics in WP2 have higher clinic utilization for family planning visits across all time periods. We find significant differences between both groups for total family planning visits (p=0.007), female family planning visits (p=0.018) and male family planning visits (0.074). RREP clinics are significantly more likely to admit a person for family planning advice than comparison clinics. However, given that we could find no significant difference for WP1 communities, where the electrification of all clinics has been achieved, makes us wonder whether these differences are really a result of (partial) access to electricity through RREP mini-grids. Especially the fact that a substantial amount of comparison CHCs have access to electricity, while around 40 percent of WP2 RREP clinics do not, tells us to interpret these findings with caution.

Figure 20: Total Family Planning Visits, Female Family Planning Visits and Family Planning Visits, WP2

Total Family Planning Patients

Female Family Planning Patients

Male Family Planning Patients

6.6.5 Vaccination, ANC and PNC Patients

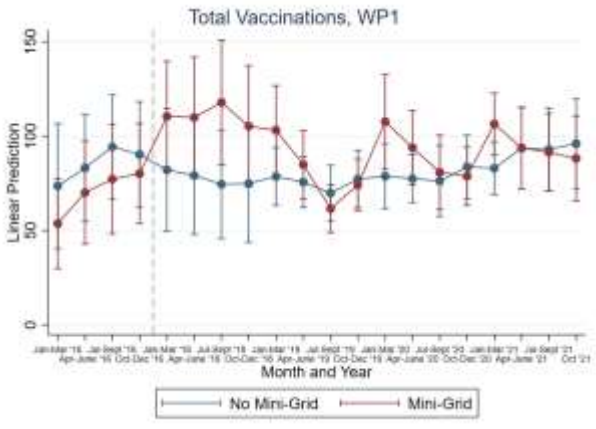
As presented in all other figures, Figures 21 and 22 below is the regression estimation between RREP clinics and comparison clinics. This figure shows data for Total Vaccinations, Total Antenatal Care Visits (ANC) and Total Prenatal Care Visits (PNC). Across all regressions there is slight variation among the RREP sites and comparison for utilization, though none are statistically significant.

6.6.5.1 Work Package 1

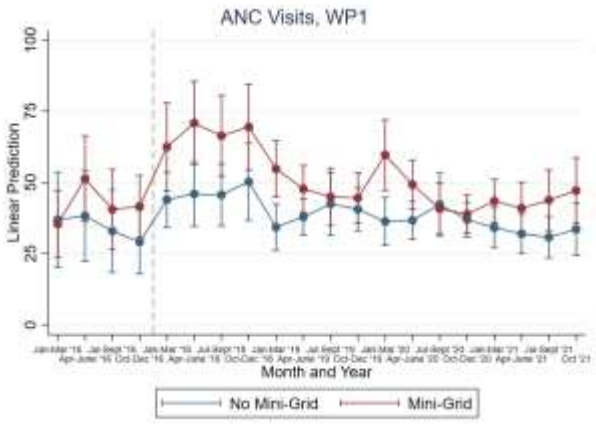
In Figure 21 we can observe substantial fluctuation in total vaccinations visits, ANC visits and PNC visits for RREP clinics. Confidence intervals are especially large for observations before 2019 and largely overlap for both groups.

Figure 21: Vaccination Visits, ANC Visits and PNC Visits, WP1

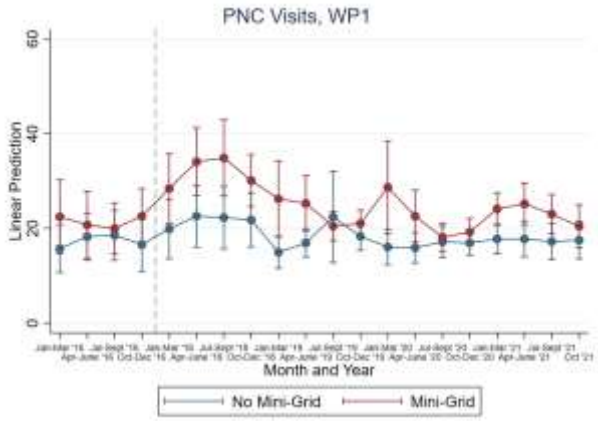
Vaccination Patients



ANC Patients



PNC Patients

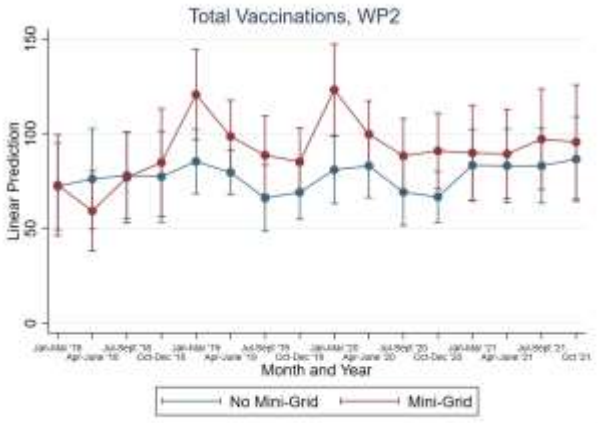


6.6.5.2 Work Package 2

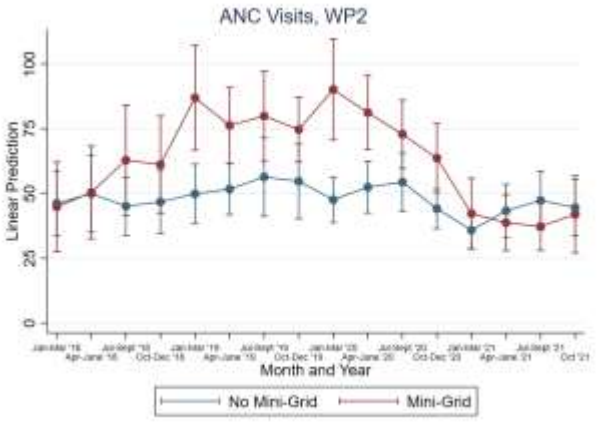
Similar to WP1, WP2 clinics as shown in Figure 22 particularly large confidence intervals and differences between RREP CHCs and comparison CHCs vary. Trends for PNC visits seem especially stable and confidence intervals largely overlap.

Figure 22: Vaccination Visits, ANC Visits and PNC Visits, WP2

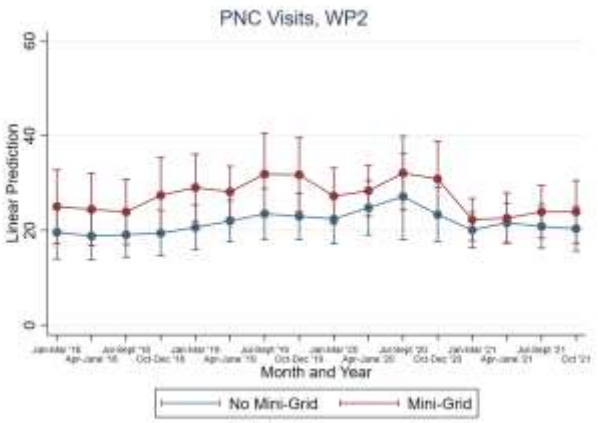
Vaccination Patients



ANC Patients



PNC Patients



The lack of significant differences suggests that clinic electrification is not sufficient to increase utilization. Electricity access must be accompanied by improvements in infrastructure, training, incentives, and appliances. Without these, it is difficult for clinics to take full advantage of the benefits of electrification. Other investments will have to be made for overall utilization of the clinics to increase, and to reap all the benefits that electrification opens up.

6.6.5 COVID-19 Vaccination

Sierra Leone obtained COVID-19 vaccinations in March 2021 from international donors and began to distribute and administer the vaccinations across the country. Tables 27 and 28 below report the summary statistics for COVID-19 vaccinations administered between March and October 2021 in project CHC's, disaggregated by treatment status. Around 46 percent of all CHC's have a COVID-19 vaccination register, however significantly more RREP CHC's have one than comparison CHC's. Row 1 shows whether a CHC has a COVID-19 registry (1) or not (0). The rest of the tables report summary statistics only for the CHC's where a COVID-19 registry was available. Row 2 reports whether the CHC administered COVID-19 vaccines in 2021 (1) or not (0), row 3 presents the number of vaccines administered and rows 4 and 5 disaggregates the number of vaccines administered by sex. The lower part of tables 31 and 32 displays the types of vaccines administered in the respective CHC's. Column 1 reports the number of observations available for the respective variable during the 8-month period of data collection. For example, we have 184 observations for RREP CHC's in WP1, thus 23 CHC's answered for each month whether they administered a COVID-19 vaccine or not. We do not have observations for all CHC's in all months, as not all CHC's had a COVID-19 register.

6.6.5.2 Work Package 1

Table 31 reports the summary statistics for COVID-19 vaccination outcomes for WP1. On average, we can see that RREP CHC's in WP1 are significantly more likely to have a COVID-19 register. Consequently, RREP clinics are more likely to administer a COVID-19 vaccine and administer more COVID-19 vaccines than comparison CHCs. For comparison CHC's COVID-19 registries were only available for the month of August, September and October, yielding only around 2 observations per month. More male patients got vaccinated against COVID-19 than

female patients, across both types of clinics. Sinopharm was the most commonly used vaccine, followed by Johnson & Johnson and Moderna.

Table 31: Summary Statistics: COVID-19 Vaccination Outcomes, WP1

	RREP CHC					Comparison				
	N (1)	Mean (2)	Median (3)	Min (4)	Max (5)	N (6)	Mean (7)	Median (8)	Min (9)	Max (10)
CHC has a COVID-19 register (binary)	272	0.68	1	0	1	288	0.22	0	0	1
CHC administered COVID-19 vaccine (binary)	184	0.35	0	0	1	64	0.17	0	0	1
Number of COVID-19 vaccines administered	56	243.36	146	0	1500	7	175.43	92	0	688
Vaccine administered to female	57	110.79	67	0	748	7	83.29	50	0	313
Vaccine administered to male	56	131.36	89	0	752	7	92.14	42	0	375
Type of vaccine										
Johnson&Johnson	56	78.79	23	0	700	6	37.00	0	0	222
Sinopharm	56	127.64	75	0	800	7	77.00	0	0	226
AsstraZeneca	57	8.79	0	0	446	6	0.00	0	0	0
Moderna	56	21.00	0	0	395	7	66.71	0	0	467
Pfizer	56	3.18	0	0	178	6	0.00	0	0	0
Sputnik	56	0.00	0	0	0	6	0.00	0	0	0

This table shows summary statistics of COVID-19 vaccination register. Column (1) is the number of observations in the analytical sample over the period from March to October 2021. Column (2) is the mean number of vaccinations over the survey period. Column (3) is the Median, and columns (4)-(5) are the minimum and maximum respectively.

6.6.5.2 Work Package 2

In table 32 we show the summary statistics for WP 2. For WP 2 we only had COVID-19 registry data for the month of August, September and October available. This leaves us with only around three observations per month per group. We observe that on average, similar to WP 1, RREP CHC's are significantly more likely to have a COVID-19 register. Therefore, they are also more likely to administer a COVID-19 vaccine and administer more COVID-19 vaccines than comparison CHCs. Vaccinations were administered to a larger number of male than female patients in RREP communities. However, this is not the case for comparison communities. Sinopharm, Johnson & Johnson and Moderna are the most commonly administered vaccines.

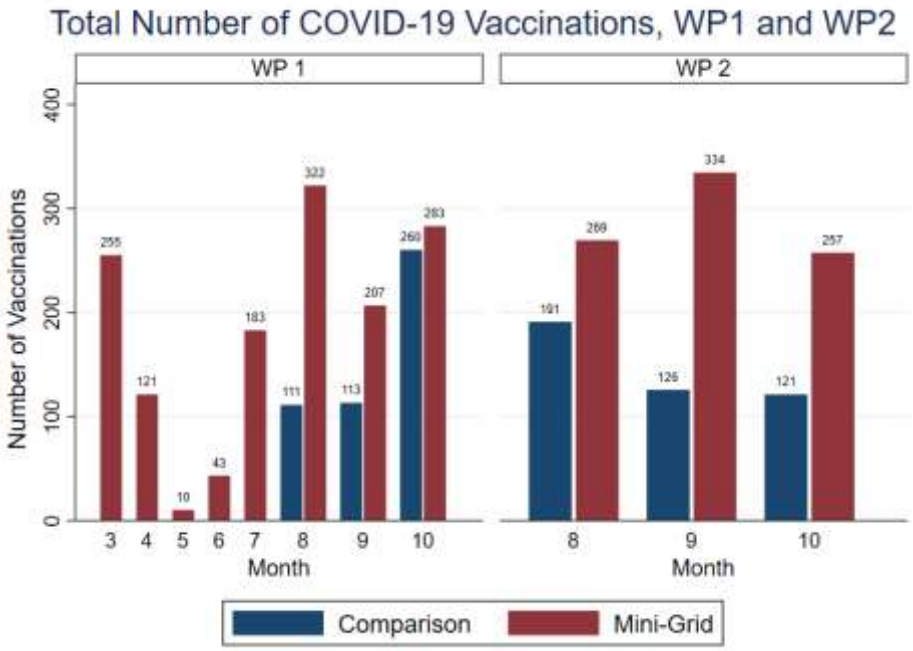
Table 32: Summary Statistics: COVID-19 Vaccination Outcomes, WP2

	RREP CHC					Comparison				
	N (1)	Mean (2)	Median (3)	Min (4)	Max (5)	N (6)	Mean (7)	Median (8)	Min (9)	Max (10)
CHC has a COVID-19 register (binary)	210	0.62	1	0	1	190	0.32	0	0	1
CHC administered COVID-19 vaccine (binary)	100	0.30	0	0	1	48	0.17	0	0	1
Number of COVID-19 vaccines administered	9	287.00	100	45	863	8	157.75	104	50	394
Vaccine administered to female	9	121.22	45	25	326	8	90.63	57	24	237
Vaccine administered to male	9	165.78	55	20	537	8	67.13	47	20	157
Type of vaccine										
Johnson&Johnson	9	43.78	20	0	234	8	78.63	28	1	394
Sinopharm	9	136.33	10	0	818	8	73.38	37	0	259
AsstraZeneca	9	2.22	0	0	20	8	0.00	0	0	0
Moderna	9	99.11	30	0	667	8	2.75	0	0	19
Pfizer	9	3.33	0	0	20	8	1.63	0	0	13
Sputnik	9	2.22	0	0	20	8	0.00	0	0	0

This table shows summary statistics of COVID-19 vaccination register. Column (1) is the number of observations in the analytical sample over the period from March to October 2021. Column (2) is the mean number of vaccinations over the survey period. Column (3) is the Median, and columns (4)-(5) are the minimum and maximum respectively.

Figure 23 below provides a comparison of the total number of Covid-19 vaccines administered each month in 2021 disaggregated by Work Package. We can see that RREP clinics in WP1 started to administer Covid-19 vaccines earlier, and continuously administered a larger number of vaccines. Similarly, RREP clinics in WP2 seem to have administered a larger number of vaccines, while it seems that WP2 CHC's overall started with the Covid-19 vaccinations later than WP1 CHC's. Those differences might be mostly driven by the fact that a larger proportion of treatment CHC's had COVID-19 registers available.

Figure 23: Total COVID-19 Vaccinations Visits over month by Work Package



7. Qualitative Report

This report provides qualitative insight into the progress of the endline data collection of the Rural Renewable Energy Project (RREP). The findings in this report are compiled from more than two dozen interviews and focus group discussions (FGDs). Over the course of November and December 2021, the Impact Evaluation team interviewed:

- Representatives of the three mini-grids operators (PowerGen, PowerLeone and Winch Energy),
- Representatives from schools and CHCs in 10 communities across the different regions of Sierra Leone,
- Four times six residents from RREP communities, and
- Two times six residents from comparison communities.

Below will show the breakdown of all FGDs and KIIs:

Focus Group Discussions		
Ministry and Operators	Quantity of FGDs	Number of People Involved
Town Chief, Stakeholders, Elders	1	7
Mammy Queen, Stakeholders	1	7
Police, Medical Staff, Chief	1	7
Town Chief, Mammy QUeen, Stakeholders	1	7
Total FGDs and Respondents	4	28

Key Informant Interviews	
Winch Energy	1
PowerGen	1
Energicity (PowerLeone)	1
School Principals	10
Community Health Centres	10
Total KIIs	23

The first section in this report will outline the general findings from the FGDs and KIIs. The second part looks at what expectations those interviewed have for WP1 and WP2 within the four domains – household and income assets, healthcare, education and CO_2 reductions. The conclusion will provide insight with recommendations for RREP stakeholders. This report finds that:

- According to the mini-grid operators, they believe that communities surrounding major cities (i.e. Bo, Kenema, Makeni) have better access to electricity, whereas more rural communities are likely to have more issues in accessing electricity due to population distribution and different value chains.
- The main constraint to bringing electricity to rural households is due to the poor road network and lack of infrastructure.
- The most common difficulties the operators are facing with WP2 are the installations and proceeding with final stages of electrification.
- All mini-grid operators have maintained their worry since the latest reporting period that the grids do not have the intended capacity to provide RREP communities with constant stable light and are needing to modify their work to tailor this. They currently are seeking to extend the capacity by building more to the grids.

7.1 Outcome domain: Household Income and Assets

- Throughout the FGDs, the common agreement among respondents was that electrification could lead to an improvement in agricultural production through several ways, and they all agreed to the following:
    - Creating space and installations of storage facilities and cooling rooms for perishable goods such as crops, meat and fish;
    - Allowing additional machinery to come and be established into the villages, such as processing machines that are labour intensive like rice mills and drying facilities;
    - And to assist with mechanized farming with different irrigation systems
- Electrification allows for the possibility of generating a range of new business opportunities, most importantly noted by all respondents are the sales of cold drinks through the acquisition of freezers by the residents. Other business opportunities include:
    - Food catering;
    - Food processing such as fruit juice shops;
    - Entertainment centres where football games or movies can be shown;
    - Barbering;
    - Tailoring;
    - And printing and scanning shops.
- Residents in WP1 and WP2 communities which have been electrified primarily acquire freezers in their homes for the sole purpose of selling cold drinks to other residents in their communities as well as neighbouring communities who do not have electricity.

7.2 Outcome domain: Improved Health

- CHC staff agree that the most important indicators of a good healthcare system are infrastructure, drug availability, electricity, water and sanitation, highly trained staff, and security. These indicators unfortunately are not currently provided by many of the health centres. Although the health staff does not have many of these needed attributes to their clinics, they do believe that they provide the best quality care for what they are able to work with.
- The main benefit that the health staff sees with the solar mini-grids is to provide electricity in the evenings. If their site has not yet been electrified all of the health staff results in using torch lights to treat patients as soon as it gets dark. Allowing for constant electricity would allow the staff to attend to patients after dark in a safer manner than they do already, especially for those coming to the clinic at night to give birth or receive treatment after a road accident.
- Many of the health staff do not have light in their quarters, even if the clinic itself is electrified. They believe that both electrification in the clinic and the clinic quarters can incentivise the staff to perform well and remain working at the clinic for a longer period of time. Without having light, many health staff members have had a high turnover rate because they would leave to go to another community where the living conditions are easier on them. Having light would allow them to feel more comfortable, secure and protected from thieves in the evening time. They could also use the electricity to charge their personal mobile phones, which could be used to call an ambulance if needed.
- The freezers that many of the health centres have have either been broken or are not large enough to hold all the needed vaccines and drugs for the size of the community. Enabling the establishment of functional freezers and stabilizers would allow safe storage of vaccines and drugs, while microscopes would enable treatment of complicated malaria or TB cases.
- Staff believe that community members would be more inclined to seek treatment in the CHC after electrification. However, some community members say that they would still go to traditional healers before going to a CHC for certain types of diseases such as malaria, common cold and HIV. CHC staff emphasize the sensitization they do within the communities in order to ensure community members refrain from going to traditional healers and go to the CHC first.

7.3 Outcome domain: Education

- School staff agree that the most important indicators for the provision of quality education are decent infrastructure, availability of water and sanitation, qualified and certified teachers and learning materials. Most of those are not currently met at the schools, although similar to the health centres they do believe that they are doing the best with what they have available.
- Many of the school principals commented that with electrification their students are now able to go to the schools during evenings to read, study, and do their homework. They

mention that this is especially helpful for those families who cannot afford any source of lighting for their children.

- The general consensus among all staff is that electrification would allow the introduction of different appliances in schools, such as televisions, laptops, photocopy machines, and printers.
- The school staff hope that the electricity will allow for digitalization of the school records rather than having a manual entry where items are easily lost or misplaced or harmed due to the weather and storing conditions.
- Acquiring electrification is believed by all principals and teachers as a needed component to ensure that the students and staff go to school more often, attract children from other communities to join, and have the potential to begin night classes.
- The main reasons for student absenteeism are children working in the home or on the farm during school time, traditional events in the community, migration, parents' unfavourable attitudes to education, and parents' inability to pay for fees that are still needed at the school.

7.4 Gender dynamics

- The mini-grid operators and members of the FGDs feel as though electrification may have stronger effects on the women than it would for men. They believe this is because women carry the majority of domestic unpaid work and benefit strongly from the introduction of electricity-powered appliances such as electric stoves and refrigerators. This in theory could eventually lead women to engage in income-generating activities, assisting in their overall household income.
- Women are deemed responsible for taking care of children in the household. If men are to step in, this is in case their wife is sick, busy, or visiting family, but overall it is not seen as a common activity.
- Most respondents mentioned that women do in fact work outside the household, but this is in tangent with their other duties as a wife, such as taking care of the house, children, and husband. They stated that the women are the first to wake up in the morning and the last to go to sleep in the evening for all the work they need to get done during the day.
- Respondents from FGDs report that decisions on the purchase of electricity-powered assets are always negotiated and discussed between husband and wife and that none of them can make decisions by themselves. However, unless the woman is making her own money and paying for household items first, she would usually require explicit permission from the husband to buy a certain appliance.

7.5 Outcome Domain: CO_2 reduction

- Firewood and charcoal are the most common methods for cooking by all households. Firewood is easier to acquire so it is sometimes used more often, whereas charcoal takes time to prepare and is a lengthier process.
- Community members state that they will switch to a different manner of cooking (i.e. wood to electricity) if the method was available and was cheaper than what they are using now.

They primarily cared about what was the most cost-effective, rather than what might be best for their health or the environment.

- The most important CO_2 reductions would be a result of many gensets being replaced with solar power. Gensets use a large amount of fossil fuel, with more fuel being used to transport it to those communities.
- Although the initial building of the mini-grids came with high CO_2 emissions, the operators are optimistic that if the systems are well-maintained there would be a large reduction in CO_2 emissions in the long run.

7.6 Qualitative Data Collection WP1 and WP2 Endline: Results

This section will discuss the findings for each of the outcome domains of the RREP, as discussed within the WP1 and WP2 communities during the recent endline data collection. The results will be from the various key informant interviews and all the focus group discussions.

The three mini-grid operators said that one of the main constraints on Sierra Leone's development is limited access to energy. It has been estimated that roughly 23% of the country currently have access to electricity, with only 2.5% of the population in rural communities having access to some form of electricity. The operators stated that regional variation in access to electricity depends on proximity to major cities. The towns who are farther away do not expect to have access to electricity, nor will it be feasible to bring to their communities for various reasons, the largest barrier being the road network.

7.6.1 Progress with WP2

The private sector operators said that community authorities and residents are generally happy and excited when mini-grids are built in their communities, with electricity representing the change needed for their livelihoods level to increase. Residents of neighbouring communities do travel to RREP communities to utilize the electricity if needed, though it has been mentioned by the operators and members of RREP communities that the neighbouring residents often complain about not being connected themselves. An issue that was raised by one of the mini-grid operators was that due to the long delay of acquiring the materials from the COVID-19 pandemic, they have had a huge delay with setting up the installations of WP2 sites. Along with the lengthy delay, it has been leading to the batteries for the mini-grids not being as strong and cannot hold the intended capacity anymore and backups are needed to have the mini-grid perform to the maximum capacity. Nonetheless, the installation and connection seem to be perceived as a form of desirable development and as a way of generating local jobs for the entire community.

The mini-grids operators thought that communities were aware of the connection fees and the costs that they will incur if they want to benefit from the mini grid. However, during site visits and phone calls with the operators, customers in WP1 and WP2 regularly complain that they are paying too much, and tariffs are too high. Residents have made comments that they are paying a higher fee than those who are in Freetown, and do not understand why they would be paying more in the rural areas compared to the main city. There has been much confusion around the

service fee of having the ability to use the electricity, as well as a daily or monthly tariff. The residents of WP1 and WP2 sites report that these fees were not communicated outside of the initial connection fee, and they do not think it is fair for them to have to pay such a high price. All mini-grid operators said they were concerned about tariffs and costs and were somewhat aware that some customers might feel like the costs for enjoying the electricity are too high. Some of the operators decided to make minor modifications to make the tariff scheme simplified for the residents to pay a monthly cost rather than every single day. They are actively trying to see what can work best with the communities as they want the grids to be a success for the residents.

> "*We initially had a few different tariff schemes to see what will be the most effective. After some time we decided to go with allocating a monthly tariff in hopes this would simplify and be easier to work with.*" – PowerLeone

All of the operators have mentioned that they are continuously being contacted about setting up new connections inside the community, and residents are consuming more electricity even if there are minor issues with the mini-grid. They did acknowledge that the batteries are quite old and so the capacity to electrify the community is not working as it should be. Each of them are taking into consideration this issue and are planning on how to expand some sites, as well as modify future sites their company will work with. Among the residents who did start benefiting from the electrification in their area, they mostly use it either for entertainment purposes, such as power for televisions and sound systems, or to store cold drinks to sell. However, according to one operator, the latter sometimes presents issues because the freezers that are bought are used ones that consume a very large amount of electricity and are very inefficient, which might make it harder for people to keep up on their bills or discourage some people from utilising the mini-grids and lead them to go back to gensets.

The collaboration between UNOPS, the Ministry of Energy and the three mini-grid operators were discussed in all interviews. All respondents were happy that UNOPS had the initiative for this project because they would not have been able to do this on their own. The operators agreed that the leadership from UNOPS has been effective and necessary in particular with creating an enabling environment and liaising with the different parties to ensure that the project runs smoothly. Regarding the collaboration between the mini-grid operators and the Ministry of Energy, the operators said that in spite of the "poor bandwidth" of the Ministry of Energy and its occasional delays and oversights, the collaboration has been cordial and they are being extremely helpful when needed.

7.6.2 Outcome Domain: Household Income and Assets

Agricultural production, non-agricultural activities, and household asset ownership were addressed in FGDs about how electrification may impact each domain. One main benefit identified by residents was that electrification could nudge them into moving towards mechanized and electrified farming, in conjunction with financial support and is something that all the residents are interested in having inside their communities. Mechanized or electrified farming is seen by them as a manner to eventually improve yields and allow the farmers to work more efficiently. If,

for instance, residents were to have a rice mill inside their community, they would then be able to spend less time than they would by milling by hand and spend less money through the use of diesel generator operated mills.

An additional benefit respondents had mentioned was their need for storage facilities and 'cooling rooms' for their crops as well as meat and fish. The freezers would enable the preservation of food items, ranging from fish and meat to fruit and vegetables. The storage facilities would keep a dry space for rice and other goods while ensuring rats and other rodents would not infest with the assistance of light. As of now, the residents are continuously having to either only prepare for the day at hand or throw away their excess food because they have no manner to preserve it for a future date.

During the FGDs, issues related to food security were discussed in relation to a subsistence farming household. When asked how food is divided among household members, respondents all responded the same and have continued to do so throughout the years of the research team conducting the FGDs with different communities. During times of hardship, food will always be prioritized for children under the age of 5 regardless of the gender of the child. The respondents were adamant that this is necessary for the children to develop properly, and this was of the most importance, whereas the parents would forego meals to ensure that the children ate as much as necessary.

Respondents identified a range of business opportunities that electrification enables. Where there is light, residents have been purchasing freezers in order to sell cold drinks and ice to the community members and the neighbouring communities. This was mostly perceived to be beneficial to women, since the majority of women are petty traders, although FGDs mentioned that both genders are equally participating in this newly found business opportunity. Electricity would also enable the preservation of prepared food, meat, or fish, which would allow caterers and others to work more efficiently, gain more income, and open new businesses. This has not yet been seen in either the WP1 or WP2 communities, but residents have been spoken about this as an option as long as they have enough capital. In relation to cattle rearing, respondents mentioned how having freezers would enable storage of vaccines for cattle and other animals to ensure that their livestock does not hold any diseases. Other FGDs respondents suggested that within the community, one person could invest in a refrigerator or freezer and that others would be able to rent fridge space.

7.6.3 Outcome Domain: Improved Health

Key Informant Interviews (KIIs) with health staff in the variety of community health centres in the WP1 and WP2 communities and FGDs shed light on the following topics:

- What do the CHOs perceive as indicators of good clinic quality;
- How CHOs perceived quality of their own facility;
- How CHOs believed their clinic would change after electrification;
- How well the staff is able to treat the most common health problems; and

- Perceptions on how treatment could change after electrification and health seeking by residents in the community.

The most important indicators of good health care delivery according to the health staff were infrastructure, drug availability, electricity, water and sanitation, qualified staff and security. As mentioned previously, most of these requirements were not met. Other problems are related to lack of mobility, availability of (working) equipment, cleanliness, lack of accommodation for staff, light for the staff quarters, lack of certified staff members and incentives for volunteer staff, and lack of financial capacity to buy drugs in times of shortages. Although the staff expressed many concerns and problems with the state of the facility, they mentioned they believe they are utilizing the most they can with what they have and are managing until more improvements come along.

The greatest impact that access to electricity can have in the health centres is the provision of light. Without electricity, the staff need to use their phones or torch lights that require constant batteries and are not ideal during evening emergencies. Light enables the health staff to conduct their routine treatments after dark and allows the health facility to stay open 24 hours a day. Electrification was found to be most impactful for the treatment of patients coming in from road accidents or for child deliveries. Communities are quite far away so many residents when traveling a distance would come through late at night when they are more susceptible to get into accidents so the CHOs have to be prepared to have someone knock at their quarters in case an accident arises. Allowing staff to see better also implies complications during childbirth can be detected more easily and staff can either take prompt action on time if they are able to deal with the complications or refer the case to the regional hospital earlier. This could thus lead to lower maternal and infant mortality. One staff member said:

> "*Many mothers are coming in late in the evenings when we have no electricity and need to be taken care of. We of course try to do our best, but if we have no light it is very difficult for us to make sure the delivery goes well.*" – CHO during a KII

However, many of the CHOs and FGD participants mentioned that they more than often get referred to the district headquarter for many of their needs that cannot be met through the health centre. Although they get the referral, they cannot always go to the main hospital for many reasons. They say that with the free health care that was provided, many of the community's members do not realize this is only for under 5 children and for mothers, so they go to the clinic and cannot be seen by the staff, and then cannot pay to go to the main district hospital either due to transport.

Electrification provides incentives to staff to stay in the clinic and do well, since staff mentioned having light makes their quarters more comfortable, they feel more secure and protected from thieves. Their main complaint is that the light they are receiving is not constant so they are still prone to injuries late at night when patients come and worry about their own security in the dark. The KIIs also showed electrification could allow the use of equipment that would improve the treatment of common health problems. According to staff, freezers would allow the safe storage of vaccines and drugs. For child deliveries, staff mentioned HB machines, oxygen plants, and

vacuum extractors would allow them better to deal with certain problems instead of referring patients to another hospital.

When asked about residents continuing to seek help from traditional healers, the staff mentioned that they are working incredibly hard to sensitize the community on coming to the health facility first. They say that occasionally members will still go to a traditional healer, but then even the healer will tell them they need to go to the clinic for treatment. This is harder for the outreach communities and the members of the community that live very far from the clinic if their situation is severe. These are typically the reasons why the residents will still choose to seek a traditional healer rather than make the trek to the clinic.

7.6.4 Outcome Domain: Education

KIIs were conducted with School Principals and headteachers addressing the indicators of good quality schools, how the school staff perceived the quality of their own school , and how they believed it could change after electrification, as well as possible reasons for low student and teacher attendance rates. Some of the schools had been electrified when conducting the interviews, while others still had not yet been connected.

Important indicators of good quality schools had not changed from the Midline to the Endline and are perceived by staff to have qualified, certified and motivated teachers, availability of learning materials, good infrastructure, and water and sanitation. Other factors mentioned were accessibility of the school to disabled students, availability of staff quarters, transport facilitation to school, availability of sports fields, having electricity, security, and the provision of meals for students. Teachers were mainly unhappy with the state of the buildings, the lack of sufficient learning materials, the lack of water and sanitation, and the lack of trained and qualified teachers. This remains consistent with the previous Baseline and Midline report when speaking with the school staff.

The general response to having access to electricity for the schools is that this should allow the teachers and students to progress even if their structure itself was not being maintained. The electricity seemed to be the key component for taking the first step into advancing since teachers and students can utilize the light to assist in grading papers and doing homework in the evening time if their days are too busy to accomplish this. According to the respondents, having electricity would allow students to come to the schools in the evenings, especially during the rainy season, and study there due to the availability of light. This would benefit students whose parents cannot afford to buy batteries for torchlights to read and study at home, as well as teachers when they want to read teaching materials.

> "*We are lucky to have been connected since we had to pay for this ourselves. We see that students who are from families who are not connected to the mini-grid will come to the school during the evening hours to try to finish their homework and study for lessons*." – KII School Principal

Respondents mentioned they would like to learn how to work with computers and teach this to students as well so they can prepare them for more jobs later and allow them to keep better records. Other machines mentioned were photocopy machines and laminating machines, as well as printers which could be used to print out exams. Electrification was perceived to make the school environment more comfortable for students to attend and for teachers to stay in the schools, because of the availability of light and the potential benefit of growing capacity and infrastructure in their communities. FGD participants confirmed having light in the schools could encourage their children to study there at nighttime and would increase the security where the students feel safe, and lead to fewer break-ins.

When asked about student attendance rates, most respondents said student attendance was high. Reasons mentioned for not attending school were distance to school (particularly during the rainy season due to the distance some of the children walk to get to school), sickness, parents moving to another town, and the occurrence of traditional events in the community. Some respondents also said parents' attitudes were problematic because some of them do not believe in education and do not care to help the students do their homework. This is more common during the farming season when students' parents would begin to have their children come help on the farm instead of going to school. Many FGD respondents mentioned that the school fees that students still need to pay are the main deterrent for students staying in school.

Teacher attendance was perceived to be mostly dependent on the teacher's status (volunteer or certified). Volunteer teachers miss school more often because of trainings and because their motivation is lower. Respondents perceived finding qualified and motivated staff as a large problem, especially to keep them in the rural areas. They reported that the distance to school and availability of accommodation and allowances for teachers were deterrents for them and they would miss school occasionally due to this.

7.6.5 Gender dynamics

Each of the mini-grid operators felt that this project is of great importance to the development of Sierra Leone, not only with regards to the four outcomes set out by UNOPS but also in terms of gender equality. All those respondents, in fact, agreed that scarce access to electricity affects women more than men since women carry out the majority of the domestic unpaid work, which could be substituted by electronic appliances such as washing machines, stoves, microwaves, and refrigerators. Better electrification in rural communities could thus play a considerable part in reducing the burden on women in terms of domestic work, which in turn may allow them to embark on profitable enterprises.

Regarding time use and division of workload, the FGDs showed an unequal division of work in the home. All FGDs mentioned that women take the responsibility of caring for the children. The men are said to go to the farm or work in their businesses during the day and that is all, whereas the women are to do the cooking, all the household chores, and take care of the children:

> "*The daily care of the household is the duty of the women in the family. They in the end do more work than the men do because the men will go to their farms at the beginning of the day and then come back at the end of the day. The women have to do all the cleaning and cooking for every meal, take care of the children and most have to work as well because the men only give a certain amount of money for the meals. Everything else has to come from the women sorting it out.*" - FGD Participant

In most cases, men reported to only help take care of the children in case their wife was sick, too busy, visiting her elders, or if there was a marital conflict. In other cases, however, responsibilities were shared as to 'keep the peace in the household'. Women were deemed responsible to take care of the husband when he gets home after farming, while most of them reported being involved in petty trading during the entire day already. Concerning food security, while women were usually reported to be the breadwinners, men were deemed responsible to bring food to the table daily. When discussing whether it is acceptable for a woman to do work outside the home, for example in another community, opinions were divided. For most of the respondents, a woman could work outside the home as long as she is providing income for the family and if she has a good reputation (some terms used were 'a sober minded person' and 'a serious person'). In discussing decision-making on household assets, most respondents said decisions were always negotiated between wife and husband.

7.6.6 Outcome Domain: CO_2 reduction

Information around energy consumption and cooking facilities was collected during the FGDs. The respondents mentioned that their primary source of light, if they were not connected to the mini-grids, was through batteries for their torchlights and radios. Most of the respondents reported using firewood for cooking purposes though they preferred to use charcoal (charcoal was perceived as being only for rich people and as a time-consuming process to make the charcoal that many do not have the time to do). Charcoal requires the resident to keep maintaining the creation process for up to a week, while collecting firewood is less time-consuming and an immediate benefit. When probed respondents mentioned that having an electric stove could in the long term make it easier for female petty traders to run their business while cooking at the same time although they did not see this being a realistic option since they had never seen it before and did not understand that this would be something they should be leaning towards. Most of the respondents mentioned that they would only switch their methods of cooking if all items were available nearby in their communities and they were the same cost, or cheaper.

> "*The only reason for us to switch our methods of cooking is if we are proven that the alternative is a cheaper method. Otherwise, we are going to continue with what we know as it is affordable and we understand it*." – Town Chief FGD participant

According to the operators, the main reduction in CO_2 that will be seen will be when residents are transitioning from generators to the use of solar power. This initial transition they say will take the most time, and will be hard to see impacts, but once they begin to move to solar it will become cheaper and more sustainable. One operator explained that while there are initial CO_2 emissions

that come with the construction of the mini-grids, in the long run, if the system is well maintained there will be a very large saving in carbon emissions.

7.7 Recommendations

Recommendations for RREP stakeholders were developed based on the findings of this report and are supported from the previous reports written.

UNOPS

1. When visiting all the communities, have clear communication to neighbouring communities about what is occurring, how the RREP communities were selected, the purpose of the project, and how they are still able to benefit while visiting the communities nearby.
2. Continue the communication with communities with regards to what support they will receive from the project and the key actors so as to better manage expectations (e.g., the tariff may not be reduced).

Government/Ministry of Energy

1. Be in communication with the staff at the health centres and schools to create a cohesive relationship working towards infrastructure improvements.
2. Mitigate the loss of qualified staff for health centres and schools by providing incentives in the rural areas.
3. Continue collaboration with the mini-grid operators to work towards renewable energy tax policies.

Mini-grid operators

1. Continue communication with the entire population of the community on the tariffs and service fees so the members feel seen and supported throughout the transition process.
2. Assist with understanding the process of buying top up on their meters and how the receipt is given to them.

Conclusion and Recommendations

The RREP impact evaluation intends to provide an understanding of the effect of electrification on important dimensions of welfare through rigorous data collection and analysis, and recommend policies based on those insights. The combination of quantitative and qualitative findings presented throughout this report and the previous reports submitted are meant to generate insight, necessary to understand how the programme is currently affecting beneficiaries in key areas of interest, as well as on how local stakeholders perceive mini-grid operations, both of which have consequences for programme sustainability.

We conclude with five similar recommendations to UNOPS as we did for the Midline and Baseline reports for continuation of work on the RREP and similar projects. These recommendations are based on intermediary findings: roughly, two years have passed since the commissioning of the first RREP community mini-grids, while many of the WP2 RREP sites still need to be electrified.

While the current report documents some important changes attributable to the electrification process, findings presented in this report also emphasize that a lot of the impact of mini-grid electrification is slow to come which has been mentioned throughout the reports the research team has been submitting to UNOPS over the duration of the Impact Evaluation. As a result, the current evaluation might fail to capture or under-report some of the effects of this programme as they will likely take place beyond the closing of the programme. This is something worth considering, in case the commissioner of this impact evaluation was interested in learning about the longer term impacts of electrification to inform similar investments in Sierra Leone or in other countries. The RREP provides a unique opportunity to do so with modest additional investments, allowing us to leverage the activities already implemented and the infrastructure put in place.

Recommendation 1: Longer-term impact evaluations

While the first effect of the transition from more traditional sources of energy to the (cleaner) electricity produced by the mini-grids are already observed as seen in Section 4.1.2 and 4.2.2, the benefits related to increased access to electricity seem to take a longer time to manifest which was noted from the Midline report previously submitted. This is because beneficiaries not only would need to connect to the electric grid, but they would also need to invest in technologies that increase productivity. This could be labor-enhancing technologies, or agricultural technologies that increase farm productivity for instance.

These type of investments are the ones that would be responsible for changes to be observed in farming and business practices, with the potential of transforming a the local economy by e.g. allowing the development of value chains through the transformation or preservation of specific products on site (consider the case of the cold chain, drying or other type of processing of perishable products into less perishable goods with more added value captured by local entrepreneurs) However, households have limited savings to invest in the appliances needed to start these types of economic activities.

In addition, limited access to credit markets, poor public infrastructure, and technological familiarity need to be addressed in order to capitalize on the improvements in the energy infrastructure made possible by RREP.

Recommendation 2: Increase access to productive electrified assets

While we observe high rates of connection to mini-grids, self-employed individuals in RREP communities are not more likely to use electricity in their business relative to self-employed individuals in comparison communities. Therefore, it is worth understanding what are the barriers to the adoption of (productive) electrified assets, and design interventions that could help people in RREP communities overcome these barriers. Electricity is an "enabler", and therefore one should not be discouraged or skeptical about the importance of access to electricity for (economic) development. Rather, now that the investment in the infrastructure has been made, it is important to focus on how to best design programmes that help people residing in RREP communities take full advantage of electricity and fully leverage on the investment in the infrastructure. For the benefit of other electrification programmes in Sierra Leone and elsewhere, it is important to rigorously test and document the impact of these programmes.

Low technology adoption rates are a known problem in the literature[30]. The problems have been documented for a broad range of cost effective technologies, products and behaviours which, if adopted, would improve health, education, and welfare indicators[31]. By better understanding which factors hamper the adoption of these technologies, policymakers can plan interventions to overcome these barriers. We recommend that interventions which increase the adoption of productive electrified assets in households and small businesses should be developed and rigorously tested.

Recommendation 3: Promote productive use of electricity at CHCs and schools

Schools and Community Health Clinics have increased access to electricity, although due to many of the RREP communities not being electrified, not all CHCs or schools have access. Therefore, they now are "enabled" to operate specific devices that might increase the quality of the

[30]Bryan, G., Chowdhury, S. and Mobarak, A.M. (2014), Underinvestment in a Profitable Technology: The Case of Seasonal Migration in Bangladesh. Econometrica, 82: 1671-1748. https://doi.org/10.3982/ECTA10489;Jessica Cohen, Pascaline Dupas, Free Distribution or Cost-Sharing? Evidence from a Randomized Malaria Prevention Experiment, The Quarterly Journal of Economics, Volume 125, Issue 1, February 2010, Pages 1–45, https://doi.org/10.1162/qjec.2010.125.1.1; Guiteras, Raymond and Guiteras, Raymond and Levinsohn, James and Mobarak, Ahmed Mushfiq, Demand Estimation with Strategic Complementarities: Sanitation in Bangladesh (January 2019). CEPR Discussion Paper No. DP13498, Available at SSRN: https://ssrn.com/abstract=3328509

[31]Duflo, Esther, Michael Kremer, and Jonathan Robinson. 2011. "Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya." American Economic Review, 101 (6): 2350-90.
DOI: 10.1257/aer.101.6.2350 ;Gine, X., & Yang, D. (2009). Insurance Credit and Technology Adoption: Field Experimental Evidence from Malawi. Journal of Development Economics, 1, 1-11.
https://doi.org/10.1016/j.jdeveco.2008.09.007; Meredith, Jennifer & Robinson, Jonathan & Walker, Sarah & Wydick, Bruce, 2013. "Keeping the doctor away: Experimental evidence on investment in preventative health products," Journal of Development Economics, Elsevier, vol. 105(C), pages 196-210; Mobarak AM, Dwivedi P, Bailis R, Hildemann L, Miller G. Low demand for nontraditional cookstove technologies. Proc Natl Acad Sci U S A. 2012 Jul 3;109(27):10815-20. doi: 10.1073/pnas.1115571109. Epub 2012 Jun 11. PMID: 22689941; PMCID: PMC3390883.; Tarozzi, Alessandro, Aprajit Mahajan, Brian Blackburn, Dan Kopf, Lakshmi Krishnan, and Joanne Yoong. 2014. "Micro-loans, Insecticide-Treated Bednets, and Malaria: Evidence from a Randomized Controlled Trial in Orissa, India." American Economic Review, 104 (7): 1909-41.; Meriggi, Niccolò F. & Bulte, Erwin & Mobarak, Ahmed Mushfiq, 2021. "Subsidies for technology adoption: Experimental evidence from rural Cameroon," Journal of Development Economics, Elsevier,

infrastructure. For instance, CHCs can have fridges and allow the storage of vaccines, and computers can be operated in schools to allow e-learning.

In theory, both CHCs and schools could now operate longer hours if they are the ones who have access to electricity. While this may improve the quality of the health and educational infrastructure, it is also important to think about how this can be complemented by other factors necessary for reaping the benefits of electrification. For instance, incentive schemes for workers at CHCs in rural Sierra Leone have shown promising results on utilization and health outcomes[32].

Alternatively, as we mentioned in the Midline report, policymakers might consider instituting night shifts at CHCs, now that the electricity makes the lighting at night possible allowing CHCs to operate and serve patients after it gets dark. This would require coordination with relevant government counterparts to fully exploit the potential of electrification programmes. Similarly when it comes to schools, investing in complementary inputs like teaching aids dependent on electricity, improving teacher incentives etc. will be essential to see sustained effects on learning outcomes and attendance rates.

Recommendation 4: Provide clarity and education on the mini-grid tariff structure

Based on focus group discussions, people in the RREP communities find the tariff scheme and the transparency of top up for their meters rather unclear, and they find the cost of the unit of electricity too expensive. Section 7 of this Endline report discusses the qualitative report with a detailed analysis of these concerns. It is recommended to engage in an information campaign clarifying the tariff structure and how to properly confirm how much top up with the agent on what is on their meter each day if needed. UNOPS and the mini-grid operators should take steps to reiterate the tariff and service fees with community members and listen to their complaints to see if the tariff can be reduced. While UNOPS and other stakeholders may not be able to change the price per unit of electricity, it might be worthwhile to provide incentives for the distribution and adoption of energy efficient devices, so that energy efficient devices can become more affordable to beneficiaries with the result of also making electricity units more affordable.

Recommendation 5: Improve communication with stakeholders

UNOPS would benefit by improving their 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 with the assistance of UNOPS team members. As UNOPS has handed over the RREP mini-grids to operator companies, we recommend increasing the quantity and detail of communication with key stakeholders in these communities. This will ensure there are no misconceptions regarding the scope and goals of the project.

Surrounding communities also expressed confusion and disappointment because their communities were not selected for the RREP. Communication will ease any potential future difficulties. Therefore, when visiting all the communities, UNOPS should clearly communicate to neighbouring communities how the RREP communities got selected, the purpose of the project, and the value of spillover effects from the nearby electrification projects.

[32] Deserranno, Erika. 2019. "Financial Incentives as Signals: Experimental Evidence from the Recruitment of Village Promoters in Uganda." American Economic Journal: Applied Economics, 11 (1): 277-317.

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