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REPORT

FINAL REPORT

Evaluation Design Report for the Liberia Energy Project

Activities 1 and 2

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ACRONYMS

AfDB	African Development Bank
CBA	cost-benefit analysis
CIE	Compagnie Ivoirienne d'Electricité
CMC	contract managing consultant
CSLG	Cote d’Ivoire, Liberia, Sierra Leone, and Guinea
EIB	European Investment Bank
EPA	Environmental Protection Agency
ERR	economic rate of return
EIB	European Investment Bank
ESBI	Electricity Supply Board International
GoL	Government of Liberia
GoN	Government of Norway
GSI	Gender and Social Inclusion
HFO	heavy fuel oil
HLSG	High Level Stakeholder Group
IMS	information management system
IMT	Interim Management Team
IV	instrumental variable
IPP	independent power producer
KfW	German Development Bank
kWh	kilowatt hour
LEC	Liberia Electricity Corporation
LERC	Liberian Electricity Regulatory Commission
LISGIS	Liberian Institute for Statistics and Geo-Information Systems
MCA-L	Millennium Challenge Account Liberia
MCC	Millennium Challenge Corporation
MCHPP	Mt. Coffee Hydropower Plant
MHI	Manitoba Hydro International (previous Management Services Contract)
M&E	monitoring and evaluation
MME	Ministry of Mines and Energy
MSC	management services contract
MW	megawatt
MWh	megawatt hour
RCE	rapid cycle evaluation
RCT	randomized controlled trial
SCADA	supervisory control and data acquisition
SME	small and medium enterprises
T&D	transmission and distribution
USAID	United States Agency for International Development
WB	World Bank
WTP	willingness to pay

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I. INTRODUCTION AND BACKGROUND

Insufficient access to reliable and affordable electricity severely constrains economic growth in Liberia. Only 2 percent of the population of Liberia has electricity—one of the lowest electrification rates in the world (USAID 2016). Moreover, access to on-grid electricity is very costly. The electricity tariff, which once reached $0.52 per kilowatt hour (kWh) in 2012, has since declined to $0.35 per kWh as of October 2017 (Liberia Executive Mansion 2017). However, this tariff is still one of the highest in the world due to the utility company's debts and high operating costs relative to electricity consumption, the failure of many small and one of the largest customers to pay electricity bills, exceedingly high commercial and technical loss rates, and the cost of diesel fuel for the generators that power portions of Liberia's electricity infrastructure (African Development Bank Group [AfDB] 2013; Millennium Challenge Corporation 2015a). The few households and firms that do have the means and the access to connect to grid electricity experience frequent planned and unplanned outages (Cooper 2017).

Liberia's 14-year civil war from 1989 to 2003, followed by widespread looting, resulted in the destruction of the Mt. Coffee Hydropower Plant (MCHPP)—the country's single largest source of power before 1989—and the entire transmission and distribution (T&D) network. Even by 2016, the total installed capacity was 23 megawatts (MW), a considerable reduction from a peak of 191 MW in 1989 (USAID 2016; World Bank 2011). In addition, the Liberian Electricity Corporation (LEC) lost significant technical and management capacity.

In 2015, the Millennium Challenge Corporation (MCC) partnered with the Government of Liberia (GoL) to help address the country's insufficient access to reliable and affordable electricity. Under MCC's compact with the GoL, and with The Millennium Challenge Account–Liberia (MCA-L) as the implementing agency, the $202 million Energy Project aims to modernize Liberia's energy network, extend access to electricity, and improve the quality and reliability of the country's power system. The GoL aims to connect 70 percent of Monrovia—both households and businesses—to the electricity grid by 2030.

MCC contracted with Mathematica Policy Research to conduct impact and performance evaluations of the Energy Project, which include four separate activities and related investments that address the challenges facing Liberia's power sector:

- **Activity 1:** The **Mt. Coffee Rehabilitation Activity,** which has repaired and expanded the MCHPP, providing an installed generation capacity of 88 MW
- **Activity 2:** The **Capacity Building and Sector Reform Activity,** which will support the creation of an independent regulatory agency, provide management oversight to the Liberia Electricity Corporation (LEC), and strengthen the capacity of LEC and, potentially, Liberia's Environmental Protection Agency (EPA)
- **Activity 3:** The **Mt. Coffee Support Activity,** which addresses environmental and social risks associated with the rehabilitation of MCHPP and aims to increase productive uses of electricity
- **Activity 4:** The **LEC Training Center Activity,** which aims to improve the capacity of the energy sector

In addition, the **Gender and Social Inclusion (GSI) investments** aim to strengthen the other activities by addressing issues related to poverty, social exclusion, ethnic tensions, and gender inequality in Liberia.

This report describes Mathematica's comprehensive mixed-methods approach to the impact and performance evaluations of Activities 1 and 2. The proposed evaluation designs described in this report aim to measure the impacts of and understand the changes related to the Mt. Coffee Rehabilitation Activity and the Capacity Building and Sector Reform Activity. When relevant, we will disaggregate the evaluation by key demographic dimensions to understand the programs' effects on gender and social inclusion. We plan to use a range of implementation, performance, and impact evaluation methods to answer research questions about the overarching, grid, energy sector, end user- and utility-level outcomes. Since the writing of this report, we have determined that an impact evaluation is not feasible. We describe the revised approach in Appendix A.

In this report, we propose a comprehensive mixed-methods approach to measure implementation, performance, and impacts of **Activities 1 and 2** in the Liberia Energy Project. We propose evaluation methods to answer research questions about outcomes at different levels:

- Overarching implementation outcomes
- Grid level outcomes
- Energy sector outcomes
- End user outcomes
- Utility-level outcomes

In the chapters that follow, we provide context for the evaluation and describe its planned design in further detail. In Chapter II, we present the program logic and describe the activities of the Mt. Coffee Rehabilitation Activity and the Capacity Building and Sector Reform Activity. We also review the existing literature on the impacts of increased electricity generation capacity, regulatory reform, and improved utility capacity. In Chapter III, we outline the research questions that the evaluation seeks to answer and provide an overview of the quantitative and qualitative evaluation designs and data sources that will enable us to answer these questions. In Chapter IV, we describe our approach to assessing overarching outcomes through an implementation analysis and in Chapter V, we describe the design and data sources for the performance evaluation of grid, energy sector, end-user, and utility-level outcomes. Next, in Chapter VI, we detail our original design for the quantitative impact evaluations. In Chapter VII, we describe the cost-benefit analysis and (CBA model) and outline plans for updating the parameters. The final sections of the report discuss our data collection approach (Chapter VIII), administrative issues (Chapter IX), and challenges to the evaluation studies (Chapter X). Appendix A describes our revised approach for the quantitative impact evaluations, as of April 2019.

II. OVERVIEW OF THE COMPACT AND THE INTERVENTIONS EVALUATED

In this chapter, we provide context for the evaluation of **Activities 1 and 2** by describing the project activities and the mechanisms through which we expect them to affect outcomes, as set out in the program logic. We also summarize and identify gaps in the existing literature on electricity production, regulatory reform, and utility management; and explain the contributions of this study to Liberia and the energy field.

A. Overview of the Liberia Energy Project

In 2015, MCC partnered with the GoL to stimulate economic growth and reduce poverty in Liberia through investments in road and electricity infrastructure. Under the $257 million Liberia Compact, which began in January 2016, the $202 million Energy Project aims to modernize Liberia's energy network, extend access to electricity, and improve the quality and reliability of the country's power system through four activities and cross-cutting GSI investments. Mathematica will evaluate the four activities and the GSI investments separately. This report describes our proposed evaluation designs for Activities 1 and 2.[1]

The **Mt. Coffee Rehabilitation Activity** is the largest component of the Energy Project, accounting for nearly $147 million of MCC's $202 million investment. The activity aims to increase domestic electricity generation, reduce electricity costs, and improve electricity reliability by reconstructing the MCHPP and contributing to the installation of 66 kilovolt (kv) transmission lines from MCHPP to the Paynesville and Bushrod substations. MCC is one of several donors funding the MCHPP rehabilitation, making this a unique investment for MCC given that expected outcomes and impacts hinge upon the efforts of other donor investments. Further, the Liberia Compact requires a high level of coordination with donor partners as well as significant energy sector and regulatory reform.

The MCHPP is located on the St. Paul River, about 27 kilometers northeast of the capital city, Monrovia. The plant was constructed in the 1960s and expanded in the 1970s to a capacity of 64 MW (Norplan Fichtner 2013). Prior to the civil war, the dam was damaged from high water flows and during Liberia's civil wars, power generation halted and the dam breached in 1990 after the operators were required to vacate the facility preventing operation of the spillway gates. In subsequent years, the plant's mechanical and electrical equipment was almost entirely destroyed or stolen. However, post war, in 2008, a feasibility study concluded that the plant could be rehabilitated. In 2011, before MCC's involvement, a group of donors including the Government of Norway (GoN), the German Development Bank (KfW), and the European Investment Bank (EIB), committed funding to a limited rehabilitation. Work on MCHPP began in 2012, with completion scheduled for 2015. However, the project was suspended during the Ebola virus outbreak. As a result, the dam reconstruction was delayed by a year. In addition, the GoL was no longer able to honor its funding commitment. In 2015, GoN and KfW committed additional funding to cover these cost overages. In addition, MCC began working with the active donors and the project implementation unit (PIU), committing funds to support MCHPP and

[1] The evaluation designs for Activities 3, 4 and GSI investments will be described in separate reports once these Activities are fully designed.

implement additional activities. MCC's funding began when the Liberia Compact entered into force in January 2016.

As of January 2018, the rehabilitation of the MCHPP had largely been achieved with a total installed capacity of 88 MW (of which 22MW installed capacity has been available since December 2016). (Note that the actual potential generation is seasonally dependent as MCHPP is a run of river scheme.) The effective completion of the project activity is anticipated to affect both connected households and businesses, which will benefit from an increased supply of quality and reliable electricity and, potentially, a reduced tariff. In addition, unserved households and businesses that decide to connect could benefit given the increased generation capacity (especially in the wet season). These beneficiaries will be located in Monrovia, where there is or will be grid infrastructure, or the Greater Monrovia area, where donor partners plan to build transmission and distribution infrastructure.

The **Capacity Building and Sector Reform Activity** aims to address Liberia's weak policy and regulatory environment in the energy sector by supporting key institutions. The Activity comprises three subactivities:

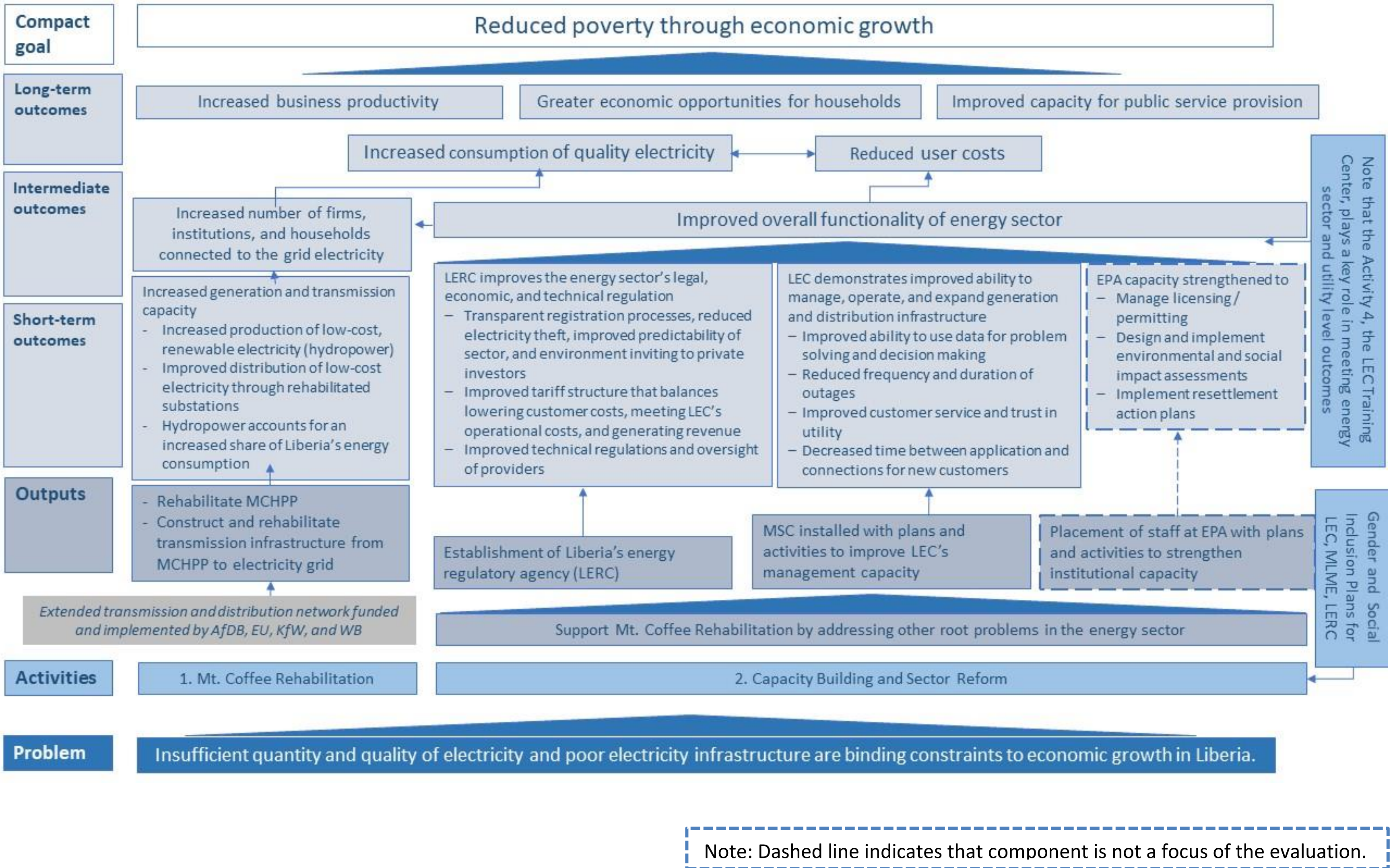
1. **Establishing the Liberia Electricity Regulatory Commission (LERC).** This activity includes support for LERC, as well as a number of studies on demand, willingness to pay, connections, and other energy sector topics. At present, the legislature had not confirmed members of the LERC commission.
2. **Installing a management services contract (MSC)** to improve LEC's management capacity. From 2010 through 2016, an external professional management company, Manitoba Hydro International (MHI), managed LEC. In general, MHI achieved its connection targets but was unable to reduce non-technical losses. Success fees for achievement of targets were paid for the period up to the Ebola crisis. However once the ebola crisis was underway, MHI struggled to achieve its performance targets in an extremely difficult social and political environment. and LEC's growth was constrained by lack of capital and political interference in tariff setting. An Interim Management Team (IMT) of local Liberians managed LEC from January 2017 until December 2017, during which time, LEC's financial and operational capabilities deterioriated. During compact development, MCC commissioned a study on various management options for LEC (MCC 2015). Informed by this study, the GoL elected to tender a new MSC for LEC. As of the writing of this report, an MSC—ESB International—was contracted and began work on January 8, 2018. The MSC will have complete operational control over LEC and assume responsibility for management and training. Although the MSC will manage LEC, the government still owns utility revenues. The new MSC will have payments tied to deliverables, including bonuses and penalties based on performance. The Millennium Challenge Account–Liberia (MCA-L) has also hired a contract managing consultant to monitor the MSC, including reviewing the MSC's monthly, quarterly, and annual reports. The contract managing consultant will assess which key performance indicators are met, and why targets were not met (Miller 2017).
3. **Support to the EPA.** MCC funding will cover placement of staff at the EPA with plans and activities to strengthen institutional capacity. Overall, this subactivity aims to improve the EPA's capacity to manage its core functions, which include environmental licensing and permitting, designing and implementing environmental and social impact assessments, and

creating resettlement action plans (MCC 2015). *Note that MCC has not yet designed this subactivity so we do not propose an evaluation in this report.*

B. Overview of the theory of change

The Energy Project's theory of change guides the evaluation of these activities. MCC first developed a high-level program logic for the full Liberia Energy Project, and a more detailed program logic for the Mt. Coffee Rehabilitation Activity. Mathematica subsequently developed two separate models to include the full level of detail available to explain the four activities and GSI investments. These models reflect the current understanding of project design. Figure II.1 illustrates the revised logic model for Activities 1 and 2.

Figure II.1. Theory of change for Activities 1 and 2 (Mathematica's version)



This logic model demonstrates how Activities 1 and 2 separately, and in concert, will theoretically lead to increased electricity generation and improved functionality of the energy sector. The figure then shows how the activities' short- and medium-term outcomes interact to produce longer-term outcomes such as increased connections, increased consumption of quality electricity, and reduced user costs. The logic model also shows how GSI plans are integrated into the Capacity Building and Sector Reform Activity.

Several assumptions related to these linkages must hold true for the theory of change to be realistic. The evaluability assessment discusses the legitimacy and relevancy of each assumption (Miller et al. 2018). The evaluation design described in this report and the separate evaluation design reports for Activities 3 and 4 will enable us to assess the accuracy of some of these assumptions. For instance, the causal linkages in the logic model depend heavily on LEC having sufficient staffing, skill, and administrative capacity to respond to users' requests for connections, and on customers trusting LEC. Mathematica's evaluation will assess the extent to which MCC's investments in the MSC and LEC training activities result in improved management and capacity at LEC.

C. Literature Review

Liberia lags behind many African countries in generating, transmitting, and distributing electricity, ranking 176th of 186 countries on the World Bank's Getting Electricity index, which measures the ease and cost of connecting, reliability of supply, and transparency of the tariff (World Bank 2017b). As a result, only 2 percent of Liberians has access to grid electricity (U.S. Agency for International Development [USAID] 2016) and nearly 75 percent of firms report owning or sharing a generator (World Bank 2017c). Public institutions also rely heavily on alternative sources of power: a 2012 survey showed that the vast majority of public hospitals and health centers relied on generators and/or solar off-grid systems for electricity, and another 40 percent lacked any form of electricity (Adair-Rohani et al. 2013). The per-kilowatt cost of energy from generators is about 10 times higher than the tariff for grid electricity, at $3.96/kWh (World Bank 2011).

We provide background on Liberia and reviewed evidence relevant to Compact activities and anticipated outcomes to provide context for this evaluation. Following the overall structure of the report, we discuss the literature related to

1. Liberia's electricity grid;
2. Energy sector policy and regulatory reform;
3. End user grid connections, electricity consumption, and impacts for households, businesses, and public institutions; and
4. Utility functioning.

We discuss gaps in the literature and how this evaluation will contribute rigorous evidence to the evidence base on the implementation, performance and impacts of energy investments in African countries.

1. Liberia's electricity network, grid infrastructure interventions, outcomes, and literature gaps

In this section, we describe the current situation of Liberia's electricity network in order to highlight the types of evidence that would inform implementation and set expectations for outcomes. Next, we describe the collaborative nature of electricity investments in Liberia. We describe the existing literature and highlight the evidence gaps.

First, Liberia's electrical grid infrastructure is concentrated in the capital area and suffers from frequent mechanical failures, having been built piecemeal through donor contributions following the civil war. In the capital Monrovia, where only 7 percent of Liberians are connected to grid electricity, the system is fragmented and fraught with mechanical and commercial challenges. Consequently, the insufficient T&D infrastructure, as well as LEC's low capacity to connect customers, means that the majority of the 88 MW of electricity generated by MCHPP is still not serving customers. The Liberia Energy Project aims to increase access to quality electricity for households, firms, and the public sector, both improving the quality of electricity for currently connected users and delivering quality electricity to an estimated 90,000 new customers.

The Liberia project would benefit from an evidence base on how to efficiently build a network in an urban setting in a post-conflict country with exceedingly low rates of connectivity. We found evidence of successful power generation projects from Rwanda, Mali, Senegal, Mauritania, and Uganda, however none of these countries began implementation with such low levels of connectivity as in Liberia. Even in these more developed countries, a World Bank study notes that many of these projects encountered implementation challenges including cost overruns, project delays, and low human resource capacity to build and repair the infrastructure (World Bank 2006; World Bank 2008).

Given the enormity of the task of electrifying Liberia, donor partners—in addition to MCC—are each planning a range of T&D investments aimed at building and reconstructing substations, installing transmission and distribution lines, feeders, and transformers (Norplan Fichtner 2013; USAID 2016, WB 2018). New T&D grid infrastructure will be funded through the African development Bank (AfDB), World Bank (WB), EIB, and KfW following a process of legislative approval of financial agreements, tender design, contracts, procurement, and implementation. These investments in Liberia's grid infrastructure are necessary, but not sufficient, to reach MCC's short-, medium-, and long-term outcomes. We did not find informative literature describing donor partners collaborating to implement electricity generation and T&D projects in sub Saharan Africa, yet there is a need for evidence that guides implementation and maximizes investment dollars and expected outcomes. Our proposed study will help fill this evidence gap and build this literature to improve implementation in Liberia and throughout developing countries where donor collaboration will be essential to meeting the goals of electrifying Africa.

Reaching Compact goals also requires efforts to overcome the existing grid's inferior performance, which is characterized by frequent outages and unreliable electricity. The grid requires better oversight, maintenance, and repair to improve its functionality. However, a major challenge is that Monrovia's limited grid network was not designed to support regular maintenance and repairs. For example, the network does not allow ‘hot line’ maintenance or repairs to be made without shutting down supply, because there is no network redundancy that allows technicians to isolate and repair the fault area. Redundancy in electrical grids allows power to be rerouted when outages occur so that repairs can be made without interrupting service. The rehabilitation has always been in an emergency phase and lacked adequate planning for redundancy. This limitation contributes to frequent and long outages, which is worsened by several ongoing rehabilitation projects that require scheduled interruptions. We did not find specific literature documenting lessons learned in building and repairing faulty T&D infrastructure. While this knowledge likely exists in the engineering field, we did not find information accessible to inform development partners so this is an important evidence gap. Our proposed forthcoming evaluation will help fill this gap by documenting the successes, challenges, and lessons learned in implementation as well as benchmarking periodic improvements in grid functionality.

We did find studies providing evidence of projects that increased generation capacity and reduced grid problems. For example, in Rwanda, a $44 million World Bank-funded increased generation capacity from 41 MW to 75 MW in six years through construction of a new thermal power plant (World Bank IEG 2012; World Bank 2010). The intervention successfully reduced load shedding (planned outages) by 50 percent during peak hours at the start of the project to no load shedding at all at its end. In Mali, the World Bank successfully installed additional power generation capacity at the Manantali dam and reportedly eliminated all load shedding in the affected region (World Bank 2006). However, in Uganda, the installation of additional generation capacity at Lake Victoria was only partially completed due to low water levels, and the installed capacity remained underutilized at the time of the evaluation (World Bank 2008).

LEC, Liberia’s government owned utility company is constrained in its ability to maintain and repair existing infrastructure. Liberian stakeholders agree that LEC struggles to prevent and respond to outages because of data limitations on the cause and location of the outages. These frequent power outages present a serious challenge to electricity quality and reliability. Further, LEC management explained that outages occur due to human errors and lack of personnel, overloaded transformers, and infrastructure and network failures. As we will describe in the utility section, human, financial, and mechanical resource shortages, and inadequate technical capacity lead to longer outages and damaged infrastructure. Currently, LEC staff log generation data hourly and send reports to management and other stakeholders on a monthly basis but this data is not used to improve real-time operations. In addition, there is insufficient detail to inform MCHPP of the problems that might causes mechanical failures and harm upstream hydropower plant components or the downstream T&D network. At the level of transmission via substation, T&D dispatcher data and substation data are collected on an hourly basis. Handwritten log books are located in each of the four substations to produce reports but they do not provide sufficient detail to locate problems or faults. Data has to be compared to historical information to determine changes over time. We found limited documentation of lessons learned from utility level interventions and rigorous evaluations of these investments. Again, our proposed evaluation will help build this evidence base to guide Liberia and other countries as they work to overcome the vast constraints to effective utility management and operations.

Another challenge to grid maintenance and improved electricity quality is the shortage of T&D equipment, such as tools, vehicles, specialized trucks, and other equipment to maintain the grid. With each donor funded energy project, Liberia inherits different types of equipment, instruments, and even generators, but not the parts to maintain the systems. Currently, Liberia has three different types of thermal power plants and equipment requiring different technical knowledge to service and maintain. As an example, while some generators use steam for startup, others use heating coils, each requiring different parts, tools, and training. Technicians must determine the parts or repairs needed for the different stations. Liberia lacks spare parts for maintenance for transformers and substation components so must rely on warranty or the defect period for replacement parts. Frequently, LEC must wait four to six weeks to receive the parts and fix system failures. During our kickoff trip discussions with LEC officials, managers expressed an immediate need for mechanisms that would enable better grid maintenance. For example, managers felt that a supervisory control and data acquisition system (SCADA), fault finders, and data loggers would produce the information needed to improve grid operations. If the utility had detailed information on the level of fault, whether it is an intermittent or permanent problem, and location, they could quickly repair grid problems improving electricity reliability and quality. LEC also reported requesting smart meters and a laboratory to repair broken transformers. Overcoming these limitations and constraints will challenge implementers, policymakers, and donors for years to come. Currently, decision makers are hampered by a lack of evidence-based information documenting what works to overcome these problems so that the utility company can effectively manage operations.

The proposed grid level study will contribute to building a foundation of learning on grid level improvements and investments. Given the substantial contextual, environmental, and technical challenges facing Liberia, high quality evidence on effective implementation and outcomes and impacts will improve the likelihood that MCC's and other donor partners' and the GoL's investments will reach their goals.

2. Energy sector outcomes

a. Overview of Liberia's energy sector

Liberia's energy sector suffers from an ineffective and inadequate policy and regulatory environment that lacks strategic and master planning, transparent regulations, and accountability. Reforms have been slow to materialize due to the low institutional capacity and inadequate investment in and management of existing infrastructure. Compounding these issues is the fact that Liberia has one of highest tariffs in the world due to high operational costs, the high cost of diesel fuel, low consumption of electricity, and excessive technical and non-technical losses.

b. Current policy reform activities

Liberia's energy sector is comprised of the Ministry of Mines and Energy (MME) (formerly the Ministry of Lands, Mines, and Energy), which is responsible for national energy policy and master plans; LEC, which is responsible for generating, transmitting, and distributing electricity; and the Rural and Renewable Energy Agency (RREA), which aims to provide electricity services to rural areas, with an emphasis on using local renewable energy sources (Sandikie 2015). Despite its policy oversight and fiscal responsibility, the MME has not yet played as significant a role in the energy sector as expected, particularly given that key positions have not been filled with experienced personnel over several years (Miller 2018). As a result, donors, rather than the government (except in a few cases where an unrealistic plan has been proposed), have guided the trajectory of the energy sector in recent years. Donor activities include installing generation capacity, T&D investments, advocating for policy and legislation, developing trainings, and commissioning sector studies.

Key developments in the energy sector in recent years include the establishment of a National Energy Policy in May 2009 and the passage of the Electricity Law of Liberia in 2015. The key features of the National Energy Policy are good governance and financial transparency; private sector investment in energy supply; and development of an independent regulatory commission, and an improved institutional and legal framework (Development & Training Services, Inc. 2013). The key purpose of the Electricity Law was to create a legal and regulatory framework for the sector. A major component was drafting the law to codify the LERC, which was established in 2017 (Sandikie 2015). Unfortunately, we found little evidence describing how energy laws lead to adequate implementation, financing, and improvements throughout the energy sector in countries like Liberia.

Liberia's 2015 National Energy Policy and the Rural Energy Strategy and Master Plan also calls for facilitating private sector investment and enabling independent power producers (IPPs) to generate electricity to meet consumer demand for power throughout Liberia (Sandikie 2015). Liberia's Electricity Law allows independent generation facilities to operate under the IPP model with a Power Purchase Agreement and LERC approval (Liberia Ministry of Foreign Affairs 2015). In most countries, IPPs, in a transparent and competitive procurement process, sell power to large industrial clients or a regional distribution company in charge of procurement outside the national grid (RREA 2016). However, in Liberia, IPPs tend to be small-scale owners of generators who sell power directly to customers. The persisting weaknesses across the sector, including the lack of clarity regarding the roles of IPPs and other stakeholders—as well as insufficient transparency, accountability, technical, performance, and security regulations and standards—hampers the IPP model. Larger IPPs are not incentivized to join the energy market and small scale IPPs are not regulated. An LERC review of this matter will start with the planned Operator Census funded by MCC.

We found a thin literature on energy sector reform in African countries, particularly in the case of a post-conflict country with such low capacity for policy making. The proposed evaluations will begin to document implementation successes, challenges, and lessons learned as well as measure performance and benchmark incremental changes over the course of the evaluation project.

c. Literature on sector reform and independent regulation

The policy and sector reforms underway in Liberia are consistent with the prevailing consensus in recent years that developing country governments should unbundle electricity utilities, establish an independent regulator, and introduce competition and private sector participation (Eberhard et al. 2016).

Liberia's establishment of an independent regulator is consistent with a worldwide movement in support of independent regulation. Since the 1990s, about 200 new infrastructure regulators have been set up around the world (Eberhard et al. 2016). The key tenet of successful regulation is independent decision making, with an emphasis on principles such as accountability, transparency, public participation, and others (Brown et al. 2006).

The key tasks of the LERC include overseeing regulatory procedures; tariff regulation, financial audits, budgets and funding; and oversight for technical regulations, quality of supply and service standards, and technical audits. Note that as a fully independent regulatory agency, the LERC has nominal oversight of the LEC. However, a key function of the LERC will be to set tariffs with the goal of maintaining a financially viable utility company. This is challenging in Liberia given ambitious goals to electrify the country, the current high and variable costs of electricity, and LEC's severe fiscal, materials, and human capacity limitations. Note that energy costs vary by season. Staff from the MME estimated that the dry season generation with heavy fuel (HFO) has a production cost of $0.49/kWh; while the wet/rainy season hydropower costs $0.20/ kWh to produce. It is not clear how the LERC will balance the desire to keep tariffs low with the financial demands of effectively operating the utility company across the seasons and investing in grid expansion. LERC has encountered delays in its start-up process, which will also delay its transition into a fully independent regulatory agency (Miller 2017).

Despite this important global shift in the structure of energy sectors, results have been mixed (Gulen et al. nd; Stern and Cubbin 2005; Eberhard et al. 2016). In some cases, regulators have lacked decision-making authority; in others, the regulators themselves have resisted further change in the sector (Brown et al. 2006; Stern and Cubbin 2005). Given that the LERC has been newly instated, with a new business plan, and newly appointed members, an independent and publicly available evaluation should contribute to the Commission's performance as an accountable and transparent agency, and ultimately help Liberia achieve energy sector goals by providing high quality data and information for decision making. As has been suggested in the literature, we will assess regulator, and the combination of institutions, laws, and processes that comprise the regulatory environment.

The proposed implementation and performance evaluations of LERC's activities as an independent regulator will provide key insights into each stage of development and implementation of the Commission, as well as insights into the sustainability of LERC once donor investments diminish.

3. End-user connections and impacts

This section reviews the literature on key end-user outcomes for this evaluation, including connections, barriers to connecting, and impacts including time allocation, education, labor market participation, and productivity. We consider impacts of *new electricity connections* and *improved quality of electricity* for households, businesses, and public institutions, as well as the potential for spillover effects.

a. End user connections

Barriers to connecting

As LEC and donors work to extend electricity lines throughout Greater Monrovia, demand and electricity consumption are expected to increase. However, households, businesses, and public institutions face a number of barriers to connecting to electricity, such as long wait times, connection costs, limited capacity of the energy utility, and information shortages. We have also heard serious concerns about mismanagement on the part of the interim management team (IMT) as well as theft of materials which has exacerbated these problems.

Connection wait times and administrative processes

The World Bank (WB) estimates that it takes 482 days for a new business in Liberia to obtain an electricity connection, about four times the regional average of 115 days (World Bank 2017b). This exceptionally long wait time is the result of LEC's inability to process applications quickly and connect new customers due to a lack of qualified personnel and a lack of equipment (Miller et al. 2018). Currently, a backlog of approximately 5,000 applicants have paid the connection fee, but are still waiting to be connected (Miller et al. 2018). These issues, as well as poor quality electricity, have resulted in a low level of trust in the utility that dampens demand. In fact, some large businesses have elected the high cost of generator use rather than connecting to the grid, which they view as too unreliable (Ballah 2017).

Potential customers may also delay electrification because they do not understand billing or administrative procedures. In Ethiopia, 41 percent of households cited administrative issues as the primary reason for not connecting to the grid (Bernard and Torero 2009). In Tanzania, Miller et al. (2015) found that households neither understood the connection process or timeline, nor made financial plans to pay for household wiring or connection fees. At the same time, respondents from health centers wanted grid connections, but reported that administrative bureaucracy prevented connections (Miller et al. 2015).

High cost of connection fees

Connection fees can be prohibitively expensive for households even though the monthly cost of grid electricity is actually lower than alternative fuel sources such as diesel-run generators (World Bank 2011). Across Africa, households pay connection fees ranging from $30 (in Ghana) to about $150 (in Benin, Cote d'Ivoire, and Uganda) to $300 or higher (in Kenya and Tanzania) (Golumbeanu and Barnes 2013). In addition to this fee, households have significant up-front payments related to the cost of wiring their dwellings (Chaplin et al. 2012; Miller et al. 2015). In Liberia, LEC had changed its policy to spread the $55 connection fee over multiple months of usage payments (Front Page Africa 2017) and then ultimately removed the connection fee entirely. Even without the utility fee however, in a country where the median household income is $781, the cost of wiring a home can impose a significant burden on poor households (Phelps and Crabtree 2013). The upfront costs of connecting or wiring, even when spread out, can be problematic compared with the low cost of batteries, candles, and kerosene, which can be purchased on an as-needed basis. These challenges are not unique to households; small businesses, health centers, and schools also report wiring and connection costs as a barrier to connection (Sovacool 2014; Miller et al. 2015). Respondents from Tanzanian health centers wanted grid connections, but reported that administrative bureaucracy and relying on the government to allocate funds were a barrier to connecting. Further, headmasters at unconnected schools explained that the costs of wiring, applying for electricity, and the monthly unit costs were a barrier, particularly for schools that could not afford desks, books, and chalk. Several unconnected schools were located too far from the new power lines to connect.

Rate of connections

The rate at which households, businesses, and public sector customers connect to electricity has varied across African countries. Several studies find relatively rapid rates of connection in the first few years after electrification, with a gradual slowing of new connections over time (Barron and Torero 2016; World Bank 2008; Lenz et al. 2017). In two studies, the remaining unconnected households could not afford the $100 connection fee (Lenz et al. 2017; World Bank 2008). There were slower connection rates in Kenya and Tanzania, where the connection fee was $300 to $400 respectively. Similarly, in rural Kenya, only 10 percent of eligible households connected five years after a community installed a transformer, a finding that the authors attribute to a high connection fee that was unaffordable even for relatively well-off households and businesses (Lee et al. 2016). Findings from Tanzania reveal similarly low rates of new connections (Chaplin et al. 2017; Winther 2007). It is important to note that most of this evidence focuses on rural areas, but urban households in the Liberian context could have different barriers and facilitators to connecting. For example, in Liberia, the WB is facilitating rapid connections with the use of ready boards, a single multi-socket outlet which is delivered to an end user by the WB contractor, eliminating the need for building wiring or LEC administrative processes. Ready boards are generally only used for residential customers given the limited supply they provide.

There is little evidence on the time it takes businesses and public institutions to connect to the grid. In rural villages in Ghana, Peters et al. (2011) found that only 34 percent of small scale manufacturing businesses had connected to the grid three to seven years after village electrification, whereas more than 80 percent of service sector businesses had connected. Manufacturing firms included dressmakers, welders, and carpentry workshops while service businesses included hairdressers, restaurants, and repair shops. The authors suggested that service firms had more to gain from electricity (entertainment, refrigeration, and longer working hours) than manufacturing firms, which used electricity primarily for lighting. In rural Kenya, only about 10 percent of small businesses had connected to the grid five years after receiving access (Lee et al. 2016). Although we were unable to find literature on the rate of new connections among public institutions, it appears that they might not be able to connect quickly if they are not located near transmission lines and if they rely on centralized government offices to allocate funding for connections.

b. Electricity consumption

In low-income countries, average annual electricity consumption among electrified households is 317 kWh per capita per year, indicating that electricity is used for limited purposes. Many studies have documented that rural households use electricity primarily for lighting (World Bank 2008; Energy Sector Management Assistance Program 2002; Bernard and Torero 2009; Lenz et al. 2017). Households may also purchase televisions, but in the short-term, they rarely rely on electricity for cooking or productive uses (Barron and Torero 2016; Bernard 2012; Bernard and Torero 2009; Lenz et al. 2017; Chaplin et al. 2017). Urban households are more likely to own electric appliances than their rural counterparts, and they rely less heavily on biofuels, but still have relatively low levels of electricity consumption (International Energy Agency (IEA) 2014).

Household Impacts

Impacts on connected households. Households with existing connections can benefit from improved electricity quality. One study in rural India found that households with improved electricity reduced kerosene consumption and time spent collecting biomass fuel. However, these households continued to rely on alternative energy sources given the imperfect electricity supply (Samad and Zhang 2016). Another study in rural India found that better-quality electricity (measured as fewer outages and more hours per day) led to an increase in households' nonagricultural income over a 10-year period.

Impacts on newly connected households. Studies in Bangladesh, India, and Tanzania find that boys and girls in electrified households *studied* one to two hours longer per week than children in non-electrified households (Khandker et al. 2012a; Khandker et al. 2012b; Chaplin et al. 2017), but in Tanzania, the increase in time spent watching television (about 73 minutes per day) was much greater. Overall, the literature is mixed on whether electricity improved school enrollment and completion (Khandker et al. 2012a; Khandker et al. 2013; Lenz et al. 2017). It is not clear how electricity will impact education and television viewing in Liberian households given the low levels of electrification and low rate of television ownership.

Adults in electrified households can benefit from spending less time collecting fuel (Grogran and Sadanand 2013; Khandker et al. 2012b; Chaplin et al. 2017), but not all studies find impacts on time allocation (Bernard and Torero 2015). Similarly, the literature does not provide a clear consensus on productive electricity use. Several studies show that households with electricity were no more likely to participate in an income-generating activity than unserved households (Bernard and Torero 2009; Wamukonya and Davis 2001; Lenz et al. 2017). However, multiple studies have indicated that electricity can lead to increased employment for women, but not for men (Khandker et al. 2012b; Grogan and Sadanand 2013; Dinkelman 2011). A study in India showed that electrification increased household per capita income and expenditures, but that the impacts were greater for wealthier households than for low-income households. Other studies have similarly found statistically significant impacts of grid electricity on income and expenditures (Chakravorty et al. 2014; Khandker et al. 2012a; Khandker et al. 2013).

Impacts on businesses

Impacts on connected businesses. Overall, the evidence suggests that poor quality and unreliable electricity hampers *productivity*, particularly for firms in electricity-intensive sectors, such as large scale manufacturing (Adenikinju 2003; Arnold et al. 2008; Escribano et al. 2010). Outages can negatively affect firms' profits and expenditures (Hardy and McCasland 2017; Adenikinju 2003) and small firms suffer the most from blackouts because they are less likely to have a back-up generation source (Adenikinju 2003). Firms with generators face higher energy costs because self-generation is considerably more expensive than grid electricity (Foster and Steinbuks 2009; Akpan et al. 2013). Unstable electricity—characterized by overloads and voltage drops—can damage electric machinery and equipment, imposing additional costs on firms (Adenikinju 2003; Foster and Steinbuks 2009). In contrast, fewer power outages may stimulate job creation, as documented in West Bengal (International Finance Corporation, Development Impact Department 2012).

Impacts on newly connected businesses. A study conducted in Rwanda suggests that businesses might benefit from access to electricity through (1) customer attraction from increased entertainment options; (2) longer hours and improved safety from electric lighting; (3) higher quality and new products and financial savings from electrical equipment; and (4) time savings from improved lighting, equipment, and communication. Qualitative findings indicate that electrification impacts were greater where there was a strong business environment and that some sectors were more likely to connect and benefit than others (Lenz et al. 2017).

Despite the potential for cost savings and increased productivity, a few quantitative studies have found no impact of a new electricity connection on firms' profits. In a study of 274 micro-manufacturers in Peters et al. (2011) found no evidence that electrification increased profits. Similarly, a study of services and manufacturing microenterprises in peri-urban areas of Ghana found no difference in working hours, labor inputs, or profits between connected and unconnected firms (Peters et al. 2013). Although Grimm et al. (2013) found positive impacts of electrification on the revenue of informal tailors in Burkina Faso's capital city, they found no positive impacts on businesses overall. It is possible that the marginal benefit of electricity over generators or traditional fuel sources is too small to yield measurable impacts on profit. It is possible that we find this scenario in Liberia as well given the frequent use of generators.

Impacts on public institutions

There is very little rigorous evidence regarding the impact of electrification on health centers and schools, but some descriptive and qualitative studies provide valuable insights into how public institutions can benefit from electrification. First, electricity might enable schools and health centers to stay open longer, as documented at health centers in Kenya (World Bank 2008) and Tanzania (Miller et al. 2015) and at schools in Rwanda (Lenz et al. 2017).

Electricity could also enable institutions to use new electrical equipment. In Rwanda, a survey of rural health centers found that 100 percent of connected centers used electricity for lighting, 79 percent used it for medical machinery, and 43 percent used it for administrative purposes (Lenz et al. 2017). However, findings from a statistical analysis showed no differences in appliance ownership based on health center connectivity, suggesting that unconnected centers may operate equipment with alternative energy sources. Headmasters in Rwanda reported that electricity improved the overall functioning of the school by facilitating computer usage, and improved the quality of education by powering computer labs (Lenz et al. 2017). Other benefits cited in these studies included improved ability to recruit skilled staff, reduced energy expenditures, and improved safety and security (Miller 2015; Lenz et al. 2017).

In Liberia, we might see muted impacts among the public institutions that switch from generator to grid electricity in Liberia unless the cost of operating a generator is significantly more than grid costs. Anecdotally, Liberians report a wide range of generator costs. In some cases, respondents may underestimate generator costs to bargain for a lower grid tariff. Further, for unserved public institutions, we do not expect many health centers or schools to purchase equipment in the short-term given the country's financial situation, however they may benefit from donor contributions or have equipment that could be used with a grid connection.

c. Spillover effects

Household electrification can have spillover effects in the surrounding community. Several studies in Africa have shown that household electrification improved perceptions of safety outside of the home (Chaplin et al. 2017; Bensch et al. 2013; Miller et al. 2015). In Rwanda, Lenz et al. (2017) found that unconnected households in connected communities reduced their use of traditional sources of lighting and their spending on batteries and kerosene, outcomes the authors attributed to outdoor lighting installed by connected households in the same neighborhood. In India, one study found economic spillovers from electrification: unconnected households' annual consumption growth rate increased by 0.8 percentage points due to residence in an electrified village (Van de Walle et al. 2015). In Rwanda, unconnected households benefitted from their neighbors' electricity through reduced expenditures on mobile phone charging (Lenz et al. 2017).

4. Utility–level outcomes

Countries throughout Sub-Saharan Africa have poor performing, state-owned utility companies that are unable to provide access to affordable and reliable electricity to swaths of the population (Eberhard et al. 2011). Further, utility companies often fail to adequately manage operations and finances, maintain and invest in new infrastructure, limit technical losses, and recover tariffs needed to cover operational costs (Kojima and Trimble 2016). In response, African countries have implemented numerous reforms in order to strengthen the performance of utility companies. For example, countries have enacted laws, encouraged private participation, privatized utilities, and established regulatory bodies. West African countries such as Cameroon, Gabon, Ghana, and Cote d'Ivoire are signing concession contracts with private firms, while the Gambia, Guinea-Bissau, Togo have signed more limited management services contracts. However a 2011 World Bank report notes that these contracts are not always successful and can be "complex and contentious". Although these contracts have some benefits, such as improving revenue and reducing loss, the contracts are often unsustainable or had long-term effects on policy and sector deficiencies (Eberhard et al. 2011). Critics of management contractors have argued that MSCs have the freedom to make staffing and collection reforms that utility companies could not make without facing a public backlash. Often governments have viewed management contracts as undesirable obligations that are required to receive donor investments. However, despite the criticisms, it is widely acknowledged that sustainable changes require improved utility management as well as broader sector reforms.

Liberia has one of the weakest utility companies in the region and the Liberia Electricity Corporation faces significant challenges in fulfilling its mission of improving access to reliable and affordable electricity. As mentioned, LEC has inadequate resources, equipment, and tools to maintain the country's limited energy infrastructure, and is severely hampered by extremely high non-technical losses (estimated at between 49 to 60 percent of losses) (ESBI, Management Services Contract 2018, Bill Hakin, Manitoba Hydro Interational report comments). The deficits are exacerbated by the complex nature of grid components. LEC is also hampered by limited technical capacity, which is partly due to Liberia's loss of professionals given the diaspora caused by war and Ebola. Poor-quality education and training programs further limits the number and capacity of new Liberian professionals entering the energy sector.

LEC's persisting low capacity has undermined efforts to electrify Liberian households and businesses. While customer demand for electricity is growing, LEC has been unable to reach targets of electrifying 11,000 new connections per year. With the current customer backlog (estimated at 5,000 applicants waiting for connections) peak load remains well below the generation potential in the rainy season through the MCHPP rehabilitation. In addition, LEC is unable to manage operations, including identifying and responding to outages. The utility lacks real-time data needed to maintain and repair the network. Further, the LEC customer database is plagued with problems and omissions including duplicate accounts and no customer classification system. A third party vendor maintains the database of prepaid customers but the data is fraught with inaccuracies. This combination of poor grid maintenance, inability to connect new users and manage current users has resulted in very low customer satisfaction and trust.

LEC was managed by Manitoba Hydro International (MHI) through a Management Services Contract from 2010 to December 2016. However, MHI fell short of its performance and financial targets and was hampered by competing donor priorities, donor and government delays, the Ebola outbreak, and conflict with the GoL (MCC 2015). We found no adequate documentation or literature describing the implementation and performance of MHI, which is unfortunate as it would help energy sector stakeholders understand the strengths and weaknesses of the contract and avoid mistakes in the new MSC. Nevertheless, we understand based on discussions that the one year gap between when MHI's MSC was completed (end December 2016) and the start of the ESB MSC on 8 January saw a significant decline in LEC's operational and financial performance.

In 2017, MCC conducted a study to identify the best management option for LEC and decided a second management services contractor was needed, with a concession being the long-term goal of the government. Subsequently, with MCC funding, LEC contracted with ESB International Engineering and Facility Management (ESBI) in January 2018 and ESBI assumed all responsibility for LEC's operations (GoL 2017). ESBI's primary goals include:

1. Creating an operationally efficient and profitable utility that is financially viable.
2. Increasing capabilities of local staff.
3. Improving quality and reliability of electricity supply and customer service.
4. Increasing the customer base (GoL 2017).

The new MSC will have a three year contract with two optional years and payments tied to deliverables, including bonuses and penalties based on performance. MCA-L has also hired a contract managing consultant (CMC) to monitor the MSC, including reviewing the MSC's monthly, quarterly, and annual reports. The contract managing consultant will assess what key performance indicators (KPIs) are met or not, and why targets were not met (Miller 2017). KPIs will measure day-to-day technical, operational, and financial performance (Tallapragada et al. 2009) and include a range of indicators. Technical and operational capabilities are reflected in compiled indicators scores of service restoration, customer service, informational technology use, and others. These indicators will be central inputs when evaluating LEC's functionality and the MSC's contribution to improving LEC's operations.

It is important to note that there has been criticism of the MSC contract in the Liberian news with the incoming administration questioning the previous administration's contracts (Front Page Africa 2018). MCA-Liberia has disputed the claims of a conflict of interest in the contract negotiation. Stakeholders agree that the MSC must have government and LEC support to carry out sustainable reforms and operational improvements. The proposed implementation and performance evaluations will be able to track support, MSC operations, and document the progress, strengths and weaknesses of the LEC with the management services contract.

5. Contribution of the proposed evaluations to the literature

Overall, the forthcoming evaluations will help fill evidence gaps on energy investments and interventions in countries that start with extremely limited infrastructure, intense energy poverty and minimal connectivity, poor technical capacity, and a nascent regulatory framework. The evaluations will answer priority implementation, performance and impact questions at the grid, energy sector, end user, and utility level particularly in a poor, post-war urban and peri-urban location. We will conduct complementary quantitative and qualitative analyses custom designed to measure a range of outcomes over the course and post-Compact. The evaluations require new data collection and sophisticated analyses of administrative data. Combined, the evaluations will generate valuable evidence and information that is not available through any other source.

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III. OVERVIEW OF EVALUATION DESIGN

In this chapter, we provide an overview of the evaluation design. We propose study designs that enable us to answer questions about MCC's energy sector investments across multiple levels, based on interventions in Activities 1 and 2 of the Compact. We also describe MCC's cost-benefit analysis (CBA) model and beneficiary analysis and present our plans for updating the CBA.

To guide our work, we will develop a conceptual map that structures and illustrates the scope of the various Compact activities and the relationships between activities, as well as their respective research questions, the evaluation studies, expected outcomes, data sources, and analyses. The conceptual map will allow us to organize these components in a comprehensive yet parsimonious approach so that we maximize the value of each data collection opportunity without repeating efforts. This level of organization and coordination is important, given that the Liberia Compact includes numerous activities and sub-activities with different implementation timelines and expected results, as well as multiple levels of outcomes and types of evaluation studies. Moreover, the Liberia Compact can only be fully achieved through donor partner investments and implementation requiring consideration of those projects' plans, progress, and achievements. Our conceptual map will guide how we approach and implement each study, including how we develop protocols for document reviews and qualitative interviews, who we interview and with whom we coordinate, when we schedule activities, and how we organize data and findings.

We present a high-level overview of the types of evaluations according to the activities and levels of questions in Table III.1. Note that there have been significant revisions to the planned impact evaluation design of end users since the report was written. See Appendix A for updates. To expand this table into a conceptual map, we will incorporate the components of measureable outcomes and concepts, data sources, and project timing to identify unique aspects of each study and areas of overlap. We present an exemplary conceptual map and key in Figure III.1.

Table III.1. Summary of the types of proposed evaluation designs

	Evaluation approaches	
	Activity 1: Mt. Coffee Rehabilitation	**Activity 2: Capacity Building and Sector Reform**
Intervention focal areas		
	Mt. Coffee Hydropower Plant (MCHPP) and substations (MCC investments), transmission and distribution (T&D) infrastructure (funded by donors partners)	MCC investments at LERC, LEC, MSC
Level of questions		
Overarching	• Implementation evaluation using mixed methods • Recomputation of economic rate of return (ERR)	• Implementation evaluation using mixed methods
Grid-level	• Longitudinal analysis of administrative data • Performance evaluation using qualitative methods	• Longitudinal analysis of administrative data • Performance evaluation using qualitative methods
Energy sector	• Longitudinal analysis of administrative data • Performance evaluation using qualitative methods	• Longitudinal analysis of administrative data • Performance evaluation using qualitative methods
End user	• Performance evaluation using quantitative methods ○ Pre-post design for connected households and small enterprises ○ Pre-post design for connected large enterprises and other customers • Impact evaluation ○ Instrumental variable (IV) strategy using natural geography OR, Matched-comparison group (MCG) design for households and small enterprises	• Longitudinal analysis of administrative data • Performance evaluation
Utility	• Longitudinal analyses of measures using administrative data • Performance evaluation using qualitative methods	• Longitudinal analyses of measures using administrative data • Performance evaluation using qualitative methods

Figure III.1. Conceptual map

Activity 1

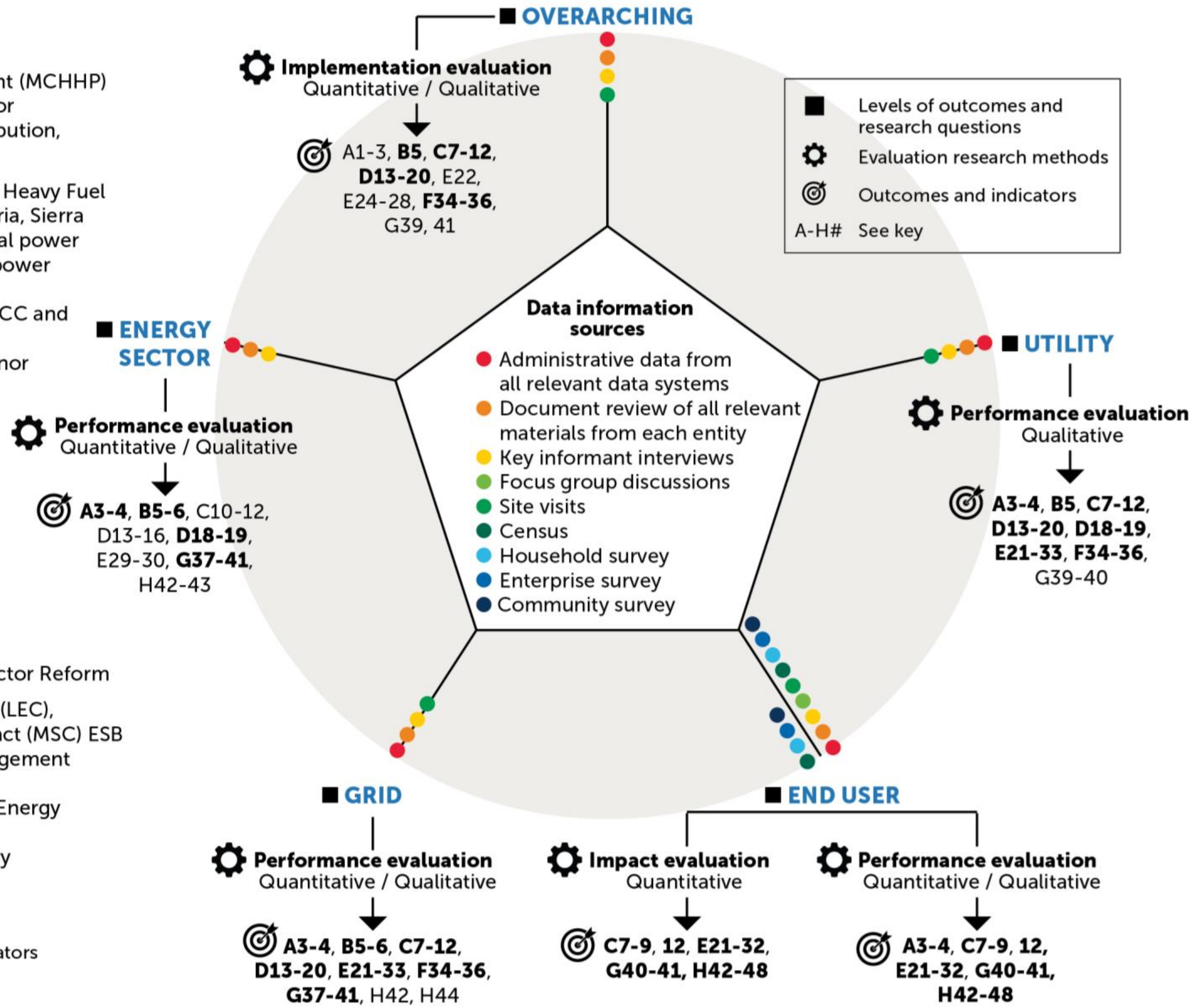
Mount Coffee Hydropower Plant (MCHHP) and supporting infrastructure for generation, transmission, distribution, and connections

- MCHHP (MCC's investment), Heavy Fuel Oil (HFO), Cote D'Ivoire, Liberia, Sierra Leone, Guinea (CLSG) regional power infrastructure, Independent power producers (IPPs)
- Substations, transformers (MCC and other donor supported)
- T&D infrastructure (other donor supported)
- Consumer connections (other donor supported)

Activity 2

Capacity Strengthening and Sector Reform

- Liberian Electricty Company (LEC), Management Services Contract (MSC) ESB International, Contract Management Consultant (CMC)
- Ministry of Lands Mines and Energy (MLME)
- Liberian Electricity Regulatory Commission (LERC)



Note: Bolded outcomes and indicators contribute to multiple analyses

Figure III.2. Indicator and outcome key to the conceptual map

A Analysis of quality, appropriateness, timeliness, strengths, weaknesses, opportunities, threats

1. Design (indicators and perceptions of indicators)
2. Implementation (indicators and perceptions of indicators)
3. Functionality and performance (indicators and perceptions of indicators)
4. Sustainability (indicators and perceptions of indicators)

B GENERATION: MCHHP/SCADA

5. Total production / generation by fuel source
6. Number, type, and size of IPPs

C LEC Transmission and distribution LEC/SCADA

7. Reliability
8. Quality
9. Voltage stability and outages
10. Peak demand shortage
11. Transformer and overhead line failure rates
12. Technical and nontechnical losses

D LEC Managment: IMS data system

13. Total energy sold
14. Consumption by user type
15. Cost recovery rates
16. Maintenance and infrastructure investments
17. Summary of infrastructure and equipment functionality and disrepair
18. Energy forecasts and gap between demand, load, and forecast, peak demand shortage
19. Technical and financial efficiency
20. Improvements to, use of IMS to measure and guide operations

E LEC Customer info; database and relevant studies

21. Number of customers by type
22. Number of new customers by type
23. Demand by customer type
24. Consumption by customer type
25. Number of applications
26. Wait time between application and connection
27. Wait time between customer call for repair and repair
28. Customer satisfaction with LEC
29. Maximum and un-served demand
30. Customer coverage and satisfaction
31. Customer pay rates and collection rates by customer type
32. Response to supply and meter complaints
33. Response time to other repairs

F LEC Staffing

34. Staff productivity index
35. Staffing retention and productivity
36. Staffing techncial capacity and gaps

G Energy Sector

37. Market structure
38. Governance
39. Regulation (status of efforts to improve legal, economic, and technical regulations, policies, and laws
40. Tariffs across user types
41. Perceptions of LERC's independence, accountability, transparency, credibility, and legitimacy

H End user

42. Energy consumption decisions and behaviors (total consumption, use of other sources, reasons for use by type)
43. Connection process, cost, barriers
44. Consumption by usage type (for households and businesses)
45. Changes in productivity and time use due to grid electricity
46. Changes in purchases, equipment use, service provision, revenue, hiring or workforce size, profit, sales due to grid electricity
47. Perceptions of quality, reliability, affordability
48. Spillover effects

A. Evaluation questions and designs

To organize this report, we present research questions for Activities 1 and 2 using MCC's original vision of outcomes at the various levels of overarching, grid, end user, energy sector, and utility. This vision frames the types of outcomes expected from MCC investments in both infrastructure and capacity strengthening, as well as sector reform across different agencies. Note that prior to writing this report, we reviewed the evaluation questions in the EA report and prioritized questions that are directly linked to the program logic (Miller et al. 2018).

We propose a comprehensive mixed methods approach to meet MCC's evaluation objectives while balancing rigor with contextual realities and local stakeholders' needs. First, we describe the *implementation analysis* to answer overarching questions about the implementation of Activities 1 and 2. Second, we describe the *performance evaluation* of Activities 1 and 2 to answer research questions and assess outcomes at the level of the grid, energy sector, end user, and utility using quantitative and qualitative data. Third, we describe the proposed *impact and quantitative evaluations* to answer questions about end-user outcomes. Findings from these various studies will be integrated and triangulated with data from other analyses to provide robust evidence for each outcome.

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IV. IMPLEMENTATION ANALYSIS OF OUTCOMES

A. Overview: Approach to assessing overarching outcomes

We will conduct an implementation analysis to answer overarching questions related to the quality, fidelity, and timing of program implementation, as well as lessons learned from implementation for Activities 1 and 2. We will employ appropriate methodologies and data sources to answer questions related to project design, implementation progress and benchmarks, successes and challenges, and their causes, and deviations from plans and the reasons for modifications. The evaluation methodologies were carefully selected to assess the intervention activities and sub-activities. In the next sections, we describe the implementation analysis of overarching questions by each level of outcome. Table IV.1 represents an overview of our approach.

Table IV.1. Research questions, evaluation designs and methods for implementation analysis

Overarching research questions	Evaluation design and methods
1. Were the activities implemented as planned? 2. What was the quality of implementation of the activities? 3. What lessons can be drawn from implementation of the activities?	Implementation analysis: • Review of quantitative administrative data, particularly measures captured in LEC's new Information Management System (IMS) funded by the WB. We will explore measures that demonstrate the quality of implementation of Activities 1 and 2, including key indicators of efforts to improve the productivity, functionality, and performance of infrastructure, the utility, and the energy sector's market structure, governance, and regulation • Review of project documents, including work plans, progress, annual and monitoring and evaluation (M&E) reports, as well as relevant media and news, and other important documents • Qualitative interviews of key informants and sector stakeholders with specific knowledge of implementation activities • Focus group discussions (FGDs) with staff (non-leadership roles) at implementing organizations • Site visits to observe and expand understanding of infrastructure, operations, and implementation that cannot be captured in written documents; presents an opportunity to ask more in-depth and relevant questions and inform future evaluation activities • Tracking implementation of Compact activities and sub-activities; complementary or contradictory interventions; relevant political events, economic shifts, energy pricing, and the contemporary societal context that affects implementation and the energy sector • Tracking the development, passage, and implementation of policies, laws, and regulations throughout the energy sector
4. To what extent, if any, does comparing the assumptions made in the forecasted economic model, actual program implementation, and evaluation findings generate lessons that can be applied to future economic models?	Cost-benefit analysis: An analysis of the ERR model, along with suggested revisions and justification as warranted

B. Methods, sample, and data sources

The implementation analysis will make use of multiple methods. We will select project documentation, interview respondents, locations of site visits, and relevant policies, laws, and regulations to ensure that we employ each methodology robustly, maximizing our ability to fully answer the research questions. For all approaches, the methodology and data sources are carefully selected to inform the evaluation and answer the research questions efficiently and comprehensively. The approach is designed to yield an understanding of processes and mechanisms in action, identify persisting questions or critical areas where further exploration is warranted to capture implementation successes and failures, and provide timely recommendations and insights. Next, we describe the methods, sample, and data sources in more detail.

First, we will draw on LEC’s available **administrative data for a longitudinal analysis** of repeated quantitative measures (see Section VI.B for a description of data collection and analyses). The MSC maintains some administrative data but is working with a contractor to build an information management system (IMS) funded by the WB. This database will contain modules on accounting, incident and outage management, customer connections and staffing. Data on power generation is available from the MCHPP SCADA system, while grid data, at least at the level of substations, will come from the WB funded SCADA system. Tracking manually collected existing data, progress on the development of digital data collection systems and the digitized measures are critical to the implementation analysis because they reveal implementation progress or delays, as well as the key outcomes of electricity generation, transmission, demand and consumption, technical capacity and losses, time to repairs, the duration and frequency of outages, and other measures. We acknowledge that data systems are lacking and flawed, however, throughout the implementation and performance evaluations we aim to identify gaps, use the data available, suggest how to fill gaps, and build on the data as investments are made and new sources become available. We will highlight data weaknesses given its importance to LEC's success as a utility. We will monitor this closely throughout the evaluation.

The **document review** will entail assessing materials such as project work plans; progress, annual, and M&E reports; timelines and schedules; and other relevant details to gain a full understanding of the design, implementation, and progress of each Compact activity as it evolves. First, we will collect documentation on the rehabilitation and construction of MCC funded MCHPP and transmission infrastructure as well as the extended transmission and distribution network funded by donor partners. This document review will allow us to assess implementation progress and quality related to increasing generation and T&D capacity. We recognize that MCC’s investments focus on generation; however, end-user outcomes are contingent upon donor partners’ T&D efforts. Reductions, changes, or delays in donor partners’ T&D investments could undermine the Compact’s success. Next, we will collect documentation of efforts by ESB International, the Management Services Contractor at LEC, to assess LEC’s improved capacity for managing the utility. We will explore documentation and explanations of the utility’s evolving capacity such as LEC’s technical and financial efficiency, customer coverage and satisfaction, and indicators of staffing retention, technical capacity, and productivity. Finally, we will collect documentation related to the establishment and activities of LERC to assess progress within the energy sector’s legal, economic, and technical regulations.

We will review and analyze emerging and adopted regulations as well as energy sector policies and laws. We will also trace the time and involvement of various actors along the route of introducing, revising, adopting, and implementing policies, laws, and regulations. We will map these elements to Compact activities and MCC and MCA's energy sector engagement.

We will conduct **interviews with key informants** (experts with specific information and knowledge of energy sector activities) and stakeholders who are in positions of interest, and conduct focus groups to address research questions related to implementation fidelity, quality, timing, and tasks, as well as lessons learned. We have already initiated interactions with key stakeholders and maintain a list of organizations and actors relevant to the proposed evaluations. We will continue to work with MCC, MCA-Liberia, LEC, and our local consultant to develop a list of relevant staff, contractors, donors, experts, and partners to interview. We anticipate interviewing representatives from MCHPP, MME, ESB International, the Contract Management Consultant (CMC), LEC, LERC, the African Development Bank (AfDB), EIB, KfW, the Norwegian Agency for Development Cooperation (NORAD), Power Africa, and the World Bank. We will keep abreast of new entries and transitions to ensure that we have an up-to-date understanding of the landscape and key stakeholders over the course of the project.

We will conduct **site visits** to observe MCC and donor partner investments in new and rehabilitated infrastructure as well as LEC operations. Site visits will expand our understanding of on-site operations that cannot be captured in written documentation and provide the opportunity to ask more in-depth questions. Additionally, site visits will help us connect project operations to outcomes, extend our understanding of the wider energy sector, and inform future rounds of data collection. We envision observing operations at LEC, various substations and MCHPP, and if possible, the LERC's offices. During observations, we will ask the hosts of our site visits to walk us through key processes that have been affected by the Compact investments and gather evidence of procedural changes. We will schedule site visits to coincide with key informant interviews.

Using all of the above inputs, we will conduct a **timeline analysis** to track the implementation of Compact activities and sub-activities; the implementation of complementary or contradictory interventions; and highly relevant political events, economic shifts, energy pricing, and the contemporary societal context in Liberia and the broader region that affect the energy sector and implementation of the Compact. We will inform the timeline analysis through regular communication with key stakeholders, document sharing, news analysis, and qualitative activities. These outcomes are expected to be achieved over the life of the Compact; therefore, we expect to collect and review implementation plans, progress reports, and other documents on a regular basis throughout the duration of the evaluation. Table IV.2 represents an overview of our approach to this task.

Table IV.2. Data sources, indicators, and timeline for implementation evaluation of Activities 1 and 2

Compact activities to assess

- Rehabilitation and construction of generation and T&D infrastructure
- Establishment of LERC
- Efforts to build LEC's capacity for management and operations by the MSC

Data sources	Indicators and concepts
Administrative data (we will request data on a monthly basis from LEC, LERC, MME)	• Electricity production, transmission, and distribution • Energy demand and consumption • Energy sector market structure, governance, and regulation • Infrastructure and equipment functionality and disrepair • LEC's management including technical capacity and gaps, and employee productivity • LEC's operations due to effective implementation (for example, electricity quality, SAIDI, SAIFI, and time to repairs) • Establishment or improvements in LEC's data collection processes • Use of data and information systems to improve utility operations
Documents (we will collect all relevant documentation on a regular basis) • Work plans, timelines, and schedules • Progress, annual, and M&E reports • Legal, economic, and technical regulations, laws, and policies • News and media on Liberian energy sector	• Quality and appropriateness of evolving design, implementation, and progress of Compact activities • Documentation of electricity generation and the extended transmission and distribution network funded by MCC and donor partners • LEC's capacity directly related to ESB International's efforts, including technical and financial efficiency, customer coverage and satisfaction, and indicators of staffing retention, technical capacity, and productivity • LERC's progress to modernize the energy sector's legal, economic, and technical regulations, policies, and laws
Interviews (to be conducted at project start and annually thereafter, or on an as-needed basis, in person or by telephone; sample size in parentheses) • MCHPP (*n* = 2) • MME and LERC (*n* =4–6) • LEC, MSC, CMC (*n* = 4–6) • MCA, EU, KfW, NORAD, Power Africa, and the World Bank (*n* = 6–10) • CIE and IPPs (*n* = 4–6)	• The design of Compact investments and their components, as well as planning and execution of contracts • Early and ongoing implementation of each activity and sub-activity, including assessment of implementation strengths, weaknesses, opportunities, and threats (SWOT analysis), as well as progress, achievements, successes, and challenges • For infrastructure improvements, perceptions of fidelity and quality of program implementation, project milestones and benchmarks, delays and challenges in project implementation, and external factors and events affecting implementation • For LEC, changes in LEC's operational, human resource, and financial management, revenue, and expenditures • For LERC, perceptions of early and ongoing functionality and productivity, including implementing the business plan and ability to fill key roles • Overall donor coordination with progress achieved, mapped to plans, coordination between organizations and donors, and SWOT analysis of multiple donor model • Assessment of and challenges to sustainability of MCHPP rehabilitation, T&D infrastructure, LEC's management and operational improvements and practices, and functionality of LERC
Site visits (conducted at 3 time points, based on implementation) • MCHPP and substations • T&D infrastructure	• Observation of operational processes and systems, procedures to handle equipment failure, use of data management systems and communication procedures, and functionality of infrastructure

Note: Some data sources and indicators are used in both implementation and performance analyses.

V. PERFORMANCE EVALUATION TO MEASURE GRID, ENERGY SECTOR, END-USER, AND UTILITY-LEVEL OUTCOMES

We will use performance evaluation methods to answer prioritized research questions that focus on understanding project achievements; estimating the contribution of Compact activities to changes in grid, energy, end-user, and utility level outcomes; and providing critical insights into the strengths and weaknesses of each component. We describe evaluation methods that will allow us to document outcomes and answer MCC's questions related to Activity 1, the rehabilitation and construction of energy infrastructure; and Activity 2: (a) LERC's efforts to improve legal, economic, and technical regulations that govern the energy sector, and (b) the MSC's success in improving LEC's management capacity. *Note that we are not proposing to evaluate capacity strengthening activities at EPA, given that this project is still in development.*

The performance evaluation will follow three basic principles. All methods will be grounded in the program logic and conceptual framework and feature ongoing, iterative data collection that reflects program implementation, as opposed to a limited schedule of traditional data collection cycles that can miss key events, processes, and milestones. The performance evaluation will entail aggregating and synthesizing findings from qualitative and quantitative data, as well as key findings from implementation and impact analyses of Activities 1 and 2 to understand program outcomes. Performance evaluation approaches will include integrating data from a longitudinal assessment of repeated measures, document review, qualitative interviews, focus group discussions, and tracking of sector reform activities. We will interpret results from impact evaluations and longitudinal studies alongside qualitative analyses to help contextualize and explain the combined results in a manner that deepens insights into complex processes. This approach expands learning from individual studies so their value is more than the sum of the discrete parts because we explore the evolution of systems and activities, in which there are many actors and processes interacting. We will identify trends and gaps across studies and processes to pinpoint key learning.

Note that the timing of project outcomes are expected to be realized at various stages throughout the life of the Compact and beyond; therefore, we expect to conduct activities on a regular or as-needed basis throughout the evaluation's duration. We explain this approach, which closely aligns with project activities and the expected timing of outcomes, in further detail in Section VI.B.

A. Grid level outcomes

1. Approach to measuring grid-level outcomes

At the grid level, we will assess the prioritized research questions using a mix of quantitative and qualitative methods, as summarized in Table V.1. We will draw on a number of methodologies and data sources to answer questions on the extent to which electricity generation, has improved grid functionality and increased the reliability and voltage stability of the electricity supply. We will also assess the extent to which energy sector reform activities have improved LEC's grid operations and maintenance directly related to electricity generation and T&D. Further, we will investigate whether and how electricity regulation, policy formulation, and monitoring activities have improved grid performance. In the next section, we describe the performance analysis of grid-level outcomes that facilitate or undermine improved electricity generation, transmission, and distribution.

Table V.1. Research questions, evaluation designs, and methods for evaluation of grid-level outcomes

Grid-level research questions and outcomes	Evaluation design, methods, and key indicators
1. To what extent, if any, has increased electricity generation contributed to increased reliability of Liberia's electricity supply, such as a reduction in planned and unplanned outages and improved voltage stability? 2. To what extent has capacity strengthening and sector reform improved LEC's operations and maintenance of the grid, so that increased generation leads to reduced outages and voltage stability? (*Revised by MPR.)* 3. To what extent, if any, have energy sector reform activities contributed to improvements in electricity regulation, policy formulation, and monitoring? How sustainable are these improvements?	Performance evaluation in which we integrate and triangulate data from multiple sources: *Note that analyses from the document and energy sector policy review, and qualitative interviews will be mapped to repeated measures of indicators of power production, T&D, and consumption to fully understand processes and mechanisms driving outcomes.* • Longitudinal analyses of repeated quantitative measures to assess indicators such as electricity generation, transmission, distribution, load factor, power availability, voltage stability and outages, consumption, number of customers, un-served demand, peak demand shortage, and transformer and overhead line failure rates • Review of documents and reports, as well as relevant media and news, that provide insights into (1) grid-level changes and (2) LEC's and the MSC's operations related to grid operations and maintenance • Qualitative key informant and stakeholder interviews, during which we will pose questions focused on a SWOT analysis of capacity strengthening and sector reform activities that facilitate or inhibit grid improvements, operations, and maintenance • Review of energy sector policies, laws, and regulations, and other evidence of activities affecting grid improvements

2. Methods, sample, outcomes, and data sources

The grid-level analysis will utilize the methods described below. We will use the conceptual mapping of studies and their components to ensure that we efficiently assess outcomes across evaluation activities. Qualitative data collection and analyses will be informed by the longitudinal analysis of quantitative measures of power production, T&D, and consumption. Next, we describe the methods, sample, and data sources in more detail.

We plan to conduct a **longitudinal analyses of repeated quantitative measures** using LEC's administrative data to assess key indicators of electricity generation, transmission, distribution, reliability, quality, consumption, and losses. A trend analysis, combined with findings from stakeholder interviews and other qualitative sources, will allow us to better understand the effect of the Compact activities, and other donors' investments on these outcomes. We will request data on a quarterly basis from LEC, MSC, and MCHPP. We will specify all data and the level of data required (grid, substation, transformer, and so on) as well as the appropriate unit of time (day, week, or month). As mentioned, we are cautious about the current state of administrative data, which must serve as a baseline in the trend analysis. However we will continue to assess the accuracy of the data, identify and highlight gaps, and incorporate additional sources of information as available. Note that we aim to subcontract Tetra Tech in order to help improve the quality and accessibility of administrative data. Next, we describe the short-term outcomes of the MCC-funded activities, or changes that would be expected to materialize within one to two years of the completion of infrastructure improvements. Key outcomes are as follows:

- **Electricity generation:** We will collect data from LEC, MCHPP, HFO plants, and transnational transmission lines as a panel over time to measure installed generation capacity (MW) and trans-border flows of electricity. We will assess seasonal variations in power generation and explore repeated measures of load factor (ratio of average annual load to maximum annual load) and percentage of time power is available.
- **Transmission and distribution:** We aim to use measures of transmission and distribution including transmission network length, losses, grid loss ratio, and measures of reliability and quality. For reliability, we plan to measure outage frequency and duration, or the system average interruption frequency index (SAIFI) and the system average interruption duration index (SAIDI), two common reliability indicators used by electric utilities[2]. Currently, outage frequency and duration is recorded manually at the 22 kV feeder line level at each substation. The WB funded SCADA system, which is not yet operating due to procurement delays and a possible funding gap, will generate data at the substation level, but not at the feeder line level. Thus, we expect to rely on the SCADA system and the handwritten, digitized data collected at the feeder line to individual transformer level until there are additional investments in a distribution SCADA system. The feeder-level measures overestimate outages because the calculation includes all customers served by a feeder line, rather than limiting to those that actually experience interruptions. For quality, we plan to measure voltage, under- and over-voltage, fluctuations, and harmonic distortions at regular intervals using both the SCADA system and LEC's manually-recorded electricity data.
- **Customer consumption:** We will use de-identified customer data to track the number of customers over time and understand growth in electricity consumption by customer type. First, we will use LEC's data on post-paid customers, which are the large end users, and constitute 10 percent of LEC's total customer base. For pre-paid customers, currently, a private vending system manages this system by registering customers, generating tokens for vending, and keeping records. We are extremely cautious about this data, so will cross reference it with field observations and surveys. We expect the data accuracy will improve once the MSC gains access to the database.
- **Technical losses:** We will use measures of total system losses, disaggregated into technical and non-technical losses. Measures include total power generation and total power delivered to end users or the difference between energy fed into and delivered along the network. While the data may not support this level of inquiry initially, over time, we want to pinpoint the losses as they occur along lines, substations, feeders and other grid components, and track changes in these losses over time. We recognize that non-technical losses, or energy theft, is the major source of loss in Liberia. We will track these losses as well as the systems and approaches to reducing energy theft. We will use LEC's administrative data, MCHPP and the WB-funded SCADA system, manually

[2] Specifically, $(\text{VI.1})\quad SAIFI = \frac{\sum \lambda_i}{N}$ where *N* is the number of customers served by the utility and λ_i is the number of interruptions for customer *i* during a specified time period; and $(\text{VI.2})\, SAIDI = \frac{\sum O_i}{N}$ where *N* is the number of customers served by the utility and O_i is the annual outage time for customer *i* in hours during a specified time period.

entered data, and field observations to track each of these losses over time, and the systems used to measure these losses.

- **Nighttime lights:** We will assess the feasibility of using nighttime lights data to measure electricity generation and reliability. It may be possible to compare baseline and follow up data (prior to and after MCHPP rehabilitation and the use of each turbine) to estimate the full impact of the MCHPP rehabilitation on the grid. By observing lit communities at regular intervals and correlating this measure with the administrative network supply data, we will have a composite longitudinal measure of the regular availability of power end users over the project life. We may be able to create a longitudinal visual of how Monrovia is "lighting up" over the course of the Compact and T&D investments. We will collect this data from the National Oceanic and Atmospheric Administration's Visible Infrared Imaging Radiometer Suite sensor. The sensor provides daily luminosity data (data on nighttime light use) at a resolution of 750 meters, typically on a one-month lag.

Building on our **document review** for the implementation analysis, we will review reports, media, and other materials that provide insights into (1) grid-level changes and (2) LEC's operations and the MSC's activities at LEC (which will be mapped to repeated measures of voltage stability and outages). We will seek reports from LEC, the MSC, the MME, LERC, MCHPP, and donor partners to extract relevant information. We will also seek reports to keep abreast of energy sources needed to meet demand during Liberia's dry season, including from heavy fuel oil (HFO) plants and the Cote d'Ivoire, Liberia, Sierra Leone, and Guinea (CLSG) transmission line, which is expected to help meet Liberia's dry season energy demand. This additional power source will be needed to meet the expected growth in demand once new customers throughout Greater Monrovia are connected to the grid. We expect that with the MSC, in place, LEC should generate data and reports that track key indicators. We will track the development, passing, and implementation of policies, laws, and regulations throughout the energy sector and map these changes to repeated measures of voltage stability and outages. We will seek guidance from key informants and experts to properly assess the contribution of these activities to grid-level changes.

We will conduct **qualitative key informant and stakeholder interviews**, posing questions focused on understanding electricity production, T&D, and consumption. We will also conduct a SWOT analysis of capacity strengthening and sector reform activities that facilitate or inhibit grid improvements. We envision interviewing respondents from LEC, ESB International, and MCA, and representatives from MCHPP, MME, LERC, the AfDB, the EU, KfW, NORAD, Power Africa, and the World Bank. Again, we will ensure that we have an up-to-date understanding of the landscape and key stakeholders over the course of the project. Table V.2 summarizes details related to this task.

Table V.2. Performance evaluation data sources and outcomes

Compact activities to assess

- Rehabilitation and construction of generation and T&D infrastructure
- Establishment of LERC
- Efforts to build LEC's capacity for management and operations by the MSC

Data source/ method of collection	Grid outcomes	Energy sector outcomes	End-user outcomes	Utility outcomes
Administrative data (we will request data on a monthly basis from LEC, LERC, MME, as described in Section VI.B Specifically, we will draw on the MCHPP SCADA, the WB funded SCADA, the MSC's IMS, donor-funded studies, and consultants' reports	• MCHPP ○ Electricity generation / production ○ Load factor ○ Power availability • LEC/SCADA ○ Transmission including substation capacity, length of transmission lines ○ Grid loss ratio ○ Distribution functionality, quality and reliability ○ Voltage stability ○ Outages using SAIDI and SAIFI across the network ○ Peak demand shortage ○ Transformer and overhead, underground line failure rates • LEC/MSC data system ○ Technical losses ○ Number of customers by type ○ Consumption by customer type ○ Annual per capita of total consumption (kWh/person) ○ Collection efficiency ○ Maximum and un-served demand	• LEC/SCADA ○ Technical losses • LEC/MSC data system ○ Number of new customers by type ○ Technical and nontechnical losses ○ Cost recovery rates ○ Maintenance and infrastructure investments • LEC/LERC ○ IPP-purchased electricity customers by type ○ Number, type, and size of IPPs ○ Tariffs across user types ○ Maximum and un-served demand	• LEC/MSC data system ○ Total energy sold by customer type ○ Number of new customers by type ○ Number of applications ○ Wait time between application and connection ○ Wait time between customer call for repair and repair ○ Customer satisfaction with LEC (based on LEC customer service data)	• MCHPP ○ Generation unit cost • LEC/SCADA ○ Transformer, overhead, and underground line failure rates • LEC/MSC data ○ Technical and financial efficiency ○ Staff productivity index ○ Staffing retention and productivity ○ Customer coverage and satisfaction ○ Customer pay rates and collection rates by customer type ○ Ability to manage customer database and accuracy of information ○ Response to supply and meter complaints ○ Debt payments • LEC/LERC ○ Energy forecasts and gap between demand, load, and forecast, peak demand shortage ○ Tariffs across user types

TABLE V.2 (CONTINUED)

Compact activities to assess

- Rehabilitation and construction of generation and T&D infrastructure
- Establishment of LERC
- Efforts to build LEC's capacity for management and operations by the MSC

Data source/ method of collection	Grid outcomes	Energy sector outcomes	End-user outcomes	Utility outcomes
Documents: on a regular basis, we will collect all relevant documentation from stakeholders and agencies, including LEC, the MSC, MME, LERC, MCHPP, and donor partners • Work plans, timelines, and schedules • Progress, annual, and M&E reports • Legal, economic, and technical regulations, laws, and policies • News and media on Liberian energy sector	• Grid-level and infrastructure changes • LEC's management of grid operations and maintenance • Emergence of energy sector policies, laws, and regulations, and other evidence of activities affecting grid improvements • Tracking the development, passage, and implementation of policies, laws, and regulations • Tracking of energy sources beyond MCHPP, including HFO plants and the CLSG transmission line	• Documentation of LERC's efforts on legal, economic, and technical regulations, including the process and dates of the introduction, passage, and implementation of regulations and laws • Identification of modernization processes affecting market structure, and sector governance and performance	• Documentation of how Activities 1 and 2 have affected new connections and energy consumption throughout Greater Monrovia for households, enterprises, industry, and the public sector	• Documentation of the MSC's efforts to strengthen LEC's capacity for management and operations

Interviews (to be conducted at project start and annually thereafter, or on an as-needed basis in person or by telephone; sample size in parentheses)
• MCHPP (*n* = 2)
• MME and LERC (*n* = 4–6)
• LEC, MSC, CMC (*n* = 4–6)
• MCA, EU, KfW, NORAD, Power Africa, and the World Bank (*n* = 6–10)
• Energy industry and IPPs (*n* = 6)
• End users
  ○ Enterprises of various sizes (*n* = 10)
  ○ Public sector (*n* =10)
• Local government (n=6)
	• Perceptions of changes in electricity production, T&D, and consumption
	• Contribution and SWOT analysis of capacity strengthening and sector reform activities that facilitate or inhibit grid improvements, operations, and maintenance
		• Perceptions of LERC's independence, accountability, transparency, credibility, and legitimacy
		• IPPs' experience with power production and sales; survivability; and registration status
		• Perceptions of Liberia's energy sector progress and persisting constraints
		• Perceptions of the formulation and timing of energy policies, laws, and regulations on sector reform, electricity consumption, quality of supply, prices and financial performance, and capacity and maintenance
			• Connection decisions, cost, process, and barriers to connecting
			• Perceptions of electricity quality, reliability, and affordability
			• Energy-related behaviors, such as changes in energy consumption and use of other energy sources
			• Based on grid connection, changes in business or service provision, use or purchase of equipment or appliances, changes in inventory, sales, revenue, profit, productivity, workforce size or composition
			• Consumption uses, and new purchases and services
			• Productivity and time use
			• Spillover effects
				• Perceptions of LEC's management and operations
				• Perceptions of MSC's efforts to bolster LEC's functionality and effectiveness as a utility
				• Perceptions of causes and trade-offs that help explain improved performance
				• Perceptions of the sustainability of plans, processes, data, and other systems

TABLE V.2 (CONTINUED)

Compact activities to assess • Rehabilitation and construction of generation and T&D infrastructure • Establishment of LERC • Efforts to build LEC's capacity for management and operations by the MSC				
Data source/ method of collection	**Grid outcomes**	**Energy sector outcomes**	**End-user outcomes**	**Utility outcomes**
Focus group discussions (n = 10, assuming 8–10 participants per FGD)				
Site visits (conducted at 3 time points, based on stage of implementation) • MCHPP and substations • T&D infrastructure • LEC and LERC				

B. Energy sector outcomes

1. Approach to measuring energy sector outcomes

To measure energy sector outcomes, we will investigate LERC activities, progress, and achievements in developing and approving the legal, economic, and technical regulations needed to modernize and improve sector-wide operations. We will assess the contributions of these activities and track changes in how IPPs operate in the energy sector. These questions, the related methods, and data sources are presented in Table V.3.

Table V.3. Research questions, evaluation designs, and methods for evaluation of energy-sector outcomes

Energy sector research question and outcomes	Evaluation design, methods, and key indicators
1. What effect, if any, have LERC activities to regulate the legal, economic, and technical environment, or changes in the availability and reliability of electricity, had on IPPs operations? **2.** What new energy policies, laws, and legal, economic, and technical regulations have been enacted or adopted, given the LERC's activities and support from the donor community? How have these contributed to modernizing the energy sector and making the sector financially viable?	Performance evaluation in which we integrate and triangulate data from multiple sources: • Longitudinal analyses of repeated quantitative measures using administrative data, including indicators of power generation, T&D, and consumption, as well as electricity purchased from IPPs, and the role, type, and size of IPPs. Further, we will track tariff rates across user types • Review and tracing of documents and reports, energy sector policies, laws, and regulations and evidence of other sector reform activities that aim to optimize electricity consumption, quality of supply, prices, and financial performance, and capacity and maintenance, which will be mapped to an event timeline to inform the interplay between changes and effects; Also review of relevant media and news, that provide insights into (1) LERC's activities around legal, economic, and technical regulations, including the process and dates of the introduction, passage, and implementation of regulations and laws; and (2) activities and events leading to the modernization of the energy sector, the market structure, and sector governance and performance. • Qualitative key informant and stakeholder interviews, with questions focused on understanding facilitators and barriers to LERC devising and adopting the policies, laws, and regulations that modernize the energy sector and improve the utility's financial standing. Also focus on perceptions of LERC's credibility, legitimacy, transparency, independence, accountability, and ability to set tariffs. Respondents will also include interviews with IPPs to understand their role, type, size, number, and experience with power production and sales.

2. Methods, sample, and data sources

The energy sector-level analysis will follow the same approach as described for the grid-level analysis. We use the conceptual mapping to ensure that we conduct evaluation activities efficiently. However, we will situate this analysis in the context of examining the functionality of the sector, including electricity production, access rates, costs, and consumption, vis-a-vis reliability of supply. As we will do in for the grid-level analysis, we will integrate qualitative and quantitative data, coordinate so that each methodology is informed by complementary activities, and use an iterative approach to maximize our understanding of the various processes and mechanisms driving outcomes. Next, we describe the methods, samples, and data sources for the analysis in more detail.

The energy sector analysis will draw on relevant indicators from the longitudinal analyses of repeated quantitative measures of administrative data, as previously described for overarching and grid-level questions. We will use repeated measures of new customer connections, maximum and un-served demand, technical and nontechnical losses, cost recovery rates, and maintenance and infrastructure investments to understand the challenges to modernization and performance of the energy sector. Further, we will use repeated measures of electricity purchased from IPPs, and the role, type, and size of IPPs to understand how changes in the energy sector have influenced participation from the private sector. Finally, we will track electricity tariffs across different types of users. Once analyzed, these data will inform instrument development, interview respondent selection, and other parts of this analysis.

As we review relevant documents, reports, and media for the energy sector assessment, we will prioritize materials that provide insights into LERC's activities focused on the legal, economic, and technical regulations, including the process and dates of the introduction, passage, and implementation of regulations and laws. We will also investigate activities and processes designed to modernize Liberia's energy sector, the market structure, and sector governance and performance. Our team will maintain regular, non-burdensome communication with LERC and other key stakeholders to ensure that we are updated on all processes and activities so that we can assess the Commission's ongoing activities. We will keep abreast of the electricity landscape through regular communication with energy stakeholders in Liberia, the region, and the wider field, and will explore the possibility of a semi-annual check-in with key energy sector actors, facilitated by MCA-Liberia. Also, we will use Google alerts and other keyword searches to monitor media outlets and maintain a library of sources that provide relevant updates and insights. We will create tools and systems to ensure that we obtain the information necessary to stay abreast of all activities.

The qualitative key informant and stakeholder interviews will focus on understanding efforts and constraints to modernizing the energy sector and improving its financial standing. We will investigate facilitators and barriers to LERC drafting and adopting the policies, laws, and regulations that set tariffs. We will interview key informants from LERC, MME, MCA and other agencies, representatives from the donor community, industry and the public sector, and IPPs. We will assess respondents' perceptions of LERC's independence, accountability, transparency, credibility, and legitimacy. We will focus questions on the then-current stage of regulatory development, cognizant that it may take years for LERC to be a fully functional and autonomous entity with complete tariff-setting authority. We will also interview representatives from IPPs to investigate their role, type, size, number, and operations relative to power production and sales. We may also seek experts outside of Liberia with specific regional knowledge of tariff-setting standards and processes to comment on Liberia's progress. We will trace the formulation and timing of the actual energy policies, laws, and regulations and evidence of other sector reform activities that aim to optimize electricity consumption, quality of supply, prices and financial performance, and capacity and maintenance, which will be mapped to an event timeline to inform the interplay between changes and effects.

C. End-user outcomes

1. Approach to measuring end-user outcomes for the performance evaluation

The **performance evaluation** will answer research questions related to end users, including households, commercial, industrial, and public sector users. This portion of the end-user performance evaluation will provide insight into outcomes that cannot be easily measured with quantitative surveys and provide additional detail to explain quantitative findings from the impact evaluation and administrative data. The research questions focus on end users' energy use, decision making around power, barriers to connecting to grid electricity, effects of grid connections, and perceptions of electricity quality, reliability, and LEC as the utility provider. Research questions related to the performance evaluation of end users are summarized in Table V.4. Note that quantitative performance and impact studies, in which we survey end users, are described in section VI.

Table V.4. Research questions, evaluation designs, and methods for evaluation of end-user outcomes

End-user research questions, outcomes, and impacts	Evaluation design, methods, and key indicators
1. To what extent, if any, have the Mt. Coffee Rehabilitation and Capacity Building and Sector Reform Activities affected the number of users connecting to the grid and the demand for electricity? 2. To what extent do customers invest in energy-intensive appliances or equipment? What is the effect of energy on time use (household production, leisure, school work, and employment)? What, if any, are the spillover effects on non-electrified households? How do all of these impacts vary by differences in gender, socioeconomic status, and other demographic characteristics? 3. How did new households, commercial, industrial, and other consumers decide to connect? For potential consumers, why have they not connected? What barriers do potential customers face when trying to connect to the grid? How have changes in the reliability of electricity affected connected and unconnected households' perceptions of the quality of electricity? Are there differences in these issues by respondents' gender and socioeconomic status?	Performance evaluation (and impact evaluations described in Section VI.C) in which we integrate and triangulate data from multiple sources: • Longitudinal analyses of repeated quantitative measures of administrative data; measures include the number of customers and new applications, wait time for applicants, electricity consumption, total energy sold, and measures of customer satisfaction with LEC • Review of documents, reports, and media that provide insights into how Activities 1 and 2 have affected new connections • Stakeholder interviews with commercial, industrial, public sector, and other consumers selected to represent a range of enterprise types and sizes to investigate decisions to connect, barriers to connecting, perceptions of electricity quality, and energy-related behaviors, such as changes in consumption, new purchases and services, and productivity • FGDs with connected and unconnected households and small enterprises to investigate decisions to connect, barriers to connecting, and energy-related behaviors, such as changes in consumption, new purchases, productivity and time use, and potential spillover effects

2. Methods, sample, and data sources

This portion of the **end-user level analysis** will draw on administrative data, stakeholder interviews and focus group discussions, and incorporate findings from the quantitative evaluations described in Section VI. First, we will draw on several indicators from the longitudinal analyses of LEC's administrative data, such as the number of new customers and applications, wait time between application and connections, electricity consumption, total energy sold, and measures of customer satisfaction with LEC. The document review will focus on material and evidence that provides insights into how Activities 1 and 2 have affected new connections. Next, we will conduct stakeholder interviews with representatives from commerce, industry, and the public sector. Respondents will be selected to represent a range of enterprises and public sector departments of different types and sizes. We will ask questions designed to investigate decisions to connect, the connection process, and the facilitators and barriers to connecting. We will also explore perceptions of electricity quality, reliability, and costs. In addition, we will ask questions related to the effects of grid electricity on operations and services, equipment purchases and usage, inventory, employment, productivity, and sales, revenue, and profits. Finally, we will conduct focus group discussions with a sample of connected and unconnected households and small enterprises. We will develop FGD protocols designed to investigate decisions by households and enterprises to connect, the connection process, and facilitators and barriers to connecting. We will also explore the energy-related behaviors of households and enterprises, such as changes in consumption, new purchases resulting from the grid connection, changes in productivity and time use relative to energy use, and potential spillover effects to other households or businesses.

D. Utility-level outcomes

1. Approach to measuring utility-level outcomes

The performance evaluation of utility-level outcomes will explore questions related to LEC management and operations. Given that we will already be examining outcomes at the grid and energy sector level for the implementation and performance evaluation, this portion of the study will focus on LEC's financial and technical operations, the electricity tariff, and changes to the utility's functionality under the MSC, and the sustainability of these changes. Table V.5 summarizes the utility-level research questions.

Table V.5. Research questions, evaluation designs, and methods for evaluation of utility-level outcomes

Utility-level research questions and outcomes	Evaluation design and methods
1. How has the electricity tariff changed since MCHPP was rehabilitated? To what extent does it cover the costs of electricity generation and other operating costs? 2. To what extent, if any, has LEC's management improved since the new management contract became effective? What progress has the GoL made toward establishing a longer-term management arrangement for LEC? 3. How sustainable is LEC as a utility? What are the biggest barriers to its sustainability?	Performance evaluation in which we integrate and triangulate data from multiple sources: • Longitudinal analyses of measures using administrative data on indicators such as tariff rates across user types, energy forecasts, and mismatch between demand, load, and forecast, peak demand shortage, transformer and overhead line failure rates, customer pay rates, collection rates, response to supply and meter complaints, generation unit cost, staff productivity index, energy lost, and other priority indicators. Data will be aligned with ESBI's key performance indicators. • Analysis of LEC management using indicator tracking, analysis of work plans, comparing plans with actual activities, systems, and processes; review of M&E reports, annual reports • Qualitative key informant and stakeholder interviews, with questions focused on LEC's management and operations, including the MSC's efforts to bolster LEC's functionality and effectiveness as a utility and the sustainability of plans, processes, data, and other systems

2. Methods, sample, and data sources

The utility-level analysis will build on the approaches and methods described in the implementation and previous performance analyses while focusing on the indicators germane to the utility-level research questions. First, we will identify relevant measures that we expect the MSC or LEC plans to collect or to which the LERC has access for a longitudinal analyses of administrative data. We will draw on measures such as generation unit costs, load, peak demand and peak demand shortage, transformer and overhead line failure rates, customer pay rates, collection rates, response to supply and meter complaints, and indicators of productivity, as well as technical and non-technical loss. We will also use tariff rates across user types. If measures are not available in the MSC's IMS or a SCADA system, we will examine agency reports for insights into these measures. Further, the document review will also focus on materials that describe the MSC's efforts to improve LEC's capacity for managing the utility. We will assess relevant work plans, systems, and processes, compare plans with actual activities, review M&E reports, quarterly and annual reports, and track management indicators. We will explore documentation and explanations of the utility's evolving capacity, such as LEC's technical and financial efficiency, customer coverage and satisfaction, and indicators of staffing retention, technical capacity, and productivity. Finally, we will conduct qualitative key informant and stakeholder interviews, which will focus on exploring questions around LEC's management and operations. We will investigate perceptions of the MSC's efforts to bolster LEC's functionality and effectiveness as a utility and the sustainability of plans, processes, data, and other systems. We will also explore the causes and tradeoffs that help explain changes in performance. We plan to interview representatives from the MSC, LEC, MME, LERC, MCA, donor partners, and others stakeholders that interact with LEC.

E. Analysis plan for the implementation and performance evaluations

As we conduct the implementation and performance evaluations, we will use the conceptual framework to guide the analysis of all data. The map will provide direction as we combine, triangulate, and synthesize quantitative and qualitative data across all evaluations. We will answer the evaluation questions by integrating data from each source. We will confirm concordant data and reports, or as necessary, reconcile discrepancies or discordant findings. Our analysis will be ongoing and iterative; information from some sources will feed into our instrument design, sampling, and data collection plans.

First, in the longitudinal analysis of administrative data, once we obtain data for a three month period, we will clean and organize them into panel data, and convert to monthly measures. Next, we will graph key outcomes over time to understand basic trends, as well as potential relationships between outcomes. For example, we plan to visualize electricity generation, distribution, and transmission over time—either on a single or multiple graphs with identical time frames—to better understand the relationships between outcomes over time. Once we have preliminary results, we will ask key stakeholders for their interpretation of the findings, including possible causes for detected trends and inflection points. We will investigate how infrastructure improvements, capacity strengthening, and sector reforms may have influenced generation, reliability, quality, and other outcomes. These analyses will inform the implementation and performance evaluations. The longitudinal analysis of administrative data will inform the implementation and performance studies. We will map these administrative data against our findings from the document review, interviews, and FGDs to fully understand the processes and mechanisms driving outcomes. For example, during qualitative interviews, we will ask respondents to reflect on quantitative indicators of outages and load shedding. In turn, during the analytic stage, we will map qualitative findings to results from the longitudinal analysis of repeated measures. This iterative approach in which we reconcile findings across data sources will facilitate our full understanding of the processes and mechanisms driving outcomes.

Second, for the document review, we will use tools such as protocols, checklists, and trackers to systematically organize, screen, categorize, and tag materials by source and topic. These procedures will help us quickly understand how documents relate to the activities and research questions and enable us to identify relevant themes that emerge from the materials. We will review new documents as they become available to track implementation and monitor sector developments related to the project activities. We will synthesize information from single files and across files, pulling critical information relevant to the each component of the energy sector studies, to inform complementary analyses and answer priority questions. Findings from the document review may reveal issues or ideas to be explored further in key informant interviews and FGDs, guiding both the protocol development and the selection of respondents.

Third, we will analyze data from qualitative interviews and FGDs using a multistep approach in which we begin by reading and rereading English transcripts to understand the respondents' experiences, identify new trends and relationships, confirm patterns or findings, and detect discrepancies or disparate experiences. Informed by the transcripts, we will develop a detailed coding strategy aligned with the research questions and logic model. This coding hierarchy will enable us to conduct a thorough word-for-word content analysis of the transcripts. The content analysis will allow us to identify the main themes that emerge across the transcripts and data types. We will use NVivo or similar qualitative data analysis software to code the transcripts, and then will review and organize resulting codes into themes that map to the logic model and are present across multiple respondents. During this process, we will identify new trends and relationships, confirm patterns or findings, and detect discrepancies or disparate experiences. Then, we will compare themes and codes by respondent type and location to identify consistent and differing themes across respondent groups.

Once we have analyzed each qualitative data source, we will triangulate findings from the administrative data, document review, interviews, FGDs, and observations. This process will facilitate identifying new trends and relationships, confirm patterns or findings, and detect discrepancies or disparate experiences. As a final step, we will integrate findings across evaluations. In particular, we will use the implementation analysis findings to contextualize impact and performance evaluation findings. We will apply this general approach to the specific types of questions and outcomes that we will examine, using each data source to a greater or lesser extent, depending on the key dimensions of focus.

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VI. PERFORMANCE AND IMPACT EVALUATIONS TO MEASURE END USER OUTCOMES

A. Overview

In Chapter V we described the performance evaluation methods to assess outcomes among end-users using administrative data and qualitative approaches. In this chapter we describe the quantitative performance evaluation methods as well as our impact evaluation plans to assess end user outcomes. The performance evaluations will provide suggestive information about potential impacts on end-user outcomes, while the impact evaluations will use comparison groups to quantify the extent to which end users (households, businesses, and public institutions) benefit from increased electricity supply and reliability. Following submission of this design report, we learned more about the approach that donor partners and LEC were implementing to connect new end users. Based on the new information, we determined that an impact evaluation with a comparison group was not feasible. The revised approach is described in Appendix A.

We designed our proposed quantitative evaluations following lengthy discussions with stakeholders and consideration of the timing of MCC's energy sector investments and donor partners' T&D investments. We know that within Monrovia, some end users were connected to the grid prior to the MCHPP rehabilitation, while some end users have only been connected since the rehabilitation. Further among connected households, some end users have benefited from improved T&D infrastructure, while others are still reliant on older lines without improved overhead and underground lines, grid feeders, and transformers. Given the implementation timing, and the fact that investments were made to an existing electricity system with some customer connections, we will not have pre-intervention, baseline data on these connected end users. Still, we aim to capture impacts on different types of connected end users—including households and small enterprises, businesses, and public institutions—and measure how they benefit from the increased electricity supply and reliability. We propose quantitative research designs for three groups of end users:

1. Households and small enterprises *connected to the grid before the intervention*, including those using existing T&D lines and those benefiting from new infrastructure
2. Medium and large enterprises and public institutions
3. Households and small enterprises *unconnected at the time of baseline survey*

For the first two groups, we propose two separate **pre-post designs**. Without pre-intervention data for these groups, we will collect retrospective data on pre-intervention measures. We propose to conduct these studies in Monrovia where the end users are concentrated.

Next, we propose an **impact evaluation** of *unconnected* households and small enterprises that will potentially benefit from grid electricity. We have explored each donor partners' T&D plans and timelines to determine the best fit for this study (see Table VI.1). For example, unserved end users along the Bomi and Kakata corridors will gain access to grid electricity when the transmission and distribution lines are built. This will enable us to assess the impacts of the increased electricity generation through MCHPP on new connections and other end user-level outcomes thereafter, noting the reduced production from MCHPP during the driest months

(January through March). We plan to conduct an impact evaluation for these users using a carefully selected comparison group. After the writing of this report, it was determined that an impact evaluation of unconnected households and small enterprises was not feasible. The reasons for this and the revised evaluation design are presented in Appendix A.

Table VI.1. List of T&D investment locations, expected number of connections, and implementation status

Location of T&D investment	Components	Expected number of connections	Status of project: Current Status	Status of project: Date of tender	Status of project: Construction begins	Status of project: Expected completion	Notes
World Bank							
Paynesville-Kakata Corridor	Transmission lines Paynesville and Kakata Substations	17,000	Implementing	N/A	July, 2017	November, 2018	Some distribution work is complete, 9 communities in Paynesville have been connected (about 17,000 customers) *Some connections through WB are only ready boards, rather than full wiring of the house or business
	Distribution network		Partially completed	N/A			
Bomi Corridor	Transmission lines Stockton Creek, Kle, Virginia, and Gardnesville substations	20,000 to 30,000	Selecting contractor	June-July, 2018 (expected)	June-July, 2018	End of 2020	The project will be completed in phases: • Replace Stockton Creek substation first to connect cement factories • Rehabilitate old substations at Virginia and then at Kle
Monrovia	Distribution network	N/A	Completed	N.A.	N.A.	Completed	Construction of 22 kV network and LV connections in 18 communities
African Development Bank (AfDB)							
Roberts International Airport (RIA) Corridor	Construction of two substations and T&D lines	25,000 to 40,000	Contract signing				The contractor was disqualified, but a new contractor will be identified.
CLSG	Construction of feeder and distribution lines	150 communities along lines	Contract signing				Construct MV/LV distribution network using shield wire technology and conventional methods
German Development Bank (KfW)							
Monrovia	Construction of feeder and distribution lines	17,500	Contractor to be recruited	April, 2018 (delayed)	Construction delayed as of May 2018	TBD (previously Dec. 2018)	Construct MV/LV network in selected communities in and around Monrovia
European Union (EU)							
Monrovia	Construction of substations and T&D lines	38,000	Contractor to be recruited	Contingent on LEC's changes on ToW	August / September, 2018	N/A	• Waterside to Motor Side to capital to Congo Town to Paynesville • LEC is proposing modifications in ToW.

N.A. = Not applicable, N/A = Not available

Table VI.2 summarizes our evaluation design approaches for each of the three groups described earlier. In the sections that follow, we detail the evaluation methods, sampling strategy, sample size requirements, and outcomes that each evaluation design will examine. As noted above, the evaluation approach for unconnected households and small enterprises has been updated. See Appendix A for the new approach.

Table VI.2. Overview of evaluation methods to estimate end user impacts

Evaluation method	Description
Connected households and small enterprises	
Longitudinal analysis (performance evaluation)	We will select a sample of connected households and small enterprises across Monrovia and compare energy-related outcomes over time to measure changes. We will collect pre-intervention data retrospectively.
Medium and large enterprises and public institutions	
Longitudinal analysis (performance evaluation)	We will follow a sample of medium and large enterprises and public institutions from Greater Monrovia and compare their energy-related outcomes over time to measure changes. We will collect pre-intervention data retrospectively. Because of the small number of large end users, we may survey the entire population.
Unconnected households and small enterprises	
Impact evaluation using natural geography to select a comparison group	In this design, we will construct a comparison group to identify the causal impacts of Activity 1 and 2 on end users by exploiting exogenous variations in their access to the electricity grid. The intervention group will be end users in communities without current access to the grid but that are part of the grid expansion plans. The comparison group will be end users in similar communities that are not part of the grid expansion plans because of natural geographic regions unrelated to their outcomes.
Matched comparison group (impact evaluation)	In this design, we will also construct a comparison group to identify causal impacts of Activity 1 and 2 on end users using a multi-stage matching process. The intervention group will be the end users in communities without current grid access, but that are part of the grid expansion plans. The comparison group will be neighborhoods without grid access (currently or planned) matched to the intervention group on community and household characteristics. We will implement this approach if the natural experiment is not feasible because of limited geographical variations across communities along the planned grid expansions.

B. Performance evaluation for connected households and small enterprises

1. Approach to measuring outcomes among household and small businesses

We will conduct a *longitudinal analysis* to examine the changes in outcomes connected end users. We will not be able to conduct a pre-intervention baseline survey for end users that are already connected, so we will have to rely on retrospective reports from survey respondents. We will focus on key outcomes of interest for which recall is likely to be accurate. To increase the accuracy, we will anchor the survey questions to specific events, such as the 2017 election season.[3]

[3] We originally proposed a matched comparison group design based on time-invariant household characteristics and recall information in addition to the pre-post analysis with pre-period data collected retrospectively. The matched comparison group design involves significant uncertainties in terms of identifying a reliable comparison group based on the limited set of time-invariant observable end user characteristics or because of the unreliability of the recall information. In addition, a matched comparison group design requires significantly more effort to match a sample of connected end users to a group of comparison end users. We consulted with MCC about these issues and decided that investing evaluation resources to carry out a matched comparison group design would not be cost effective.

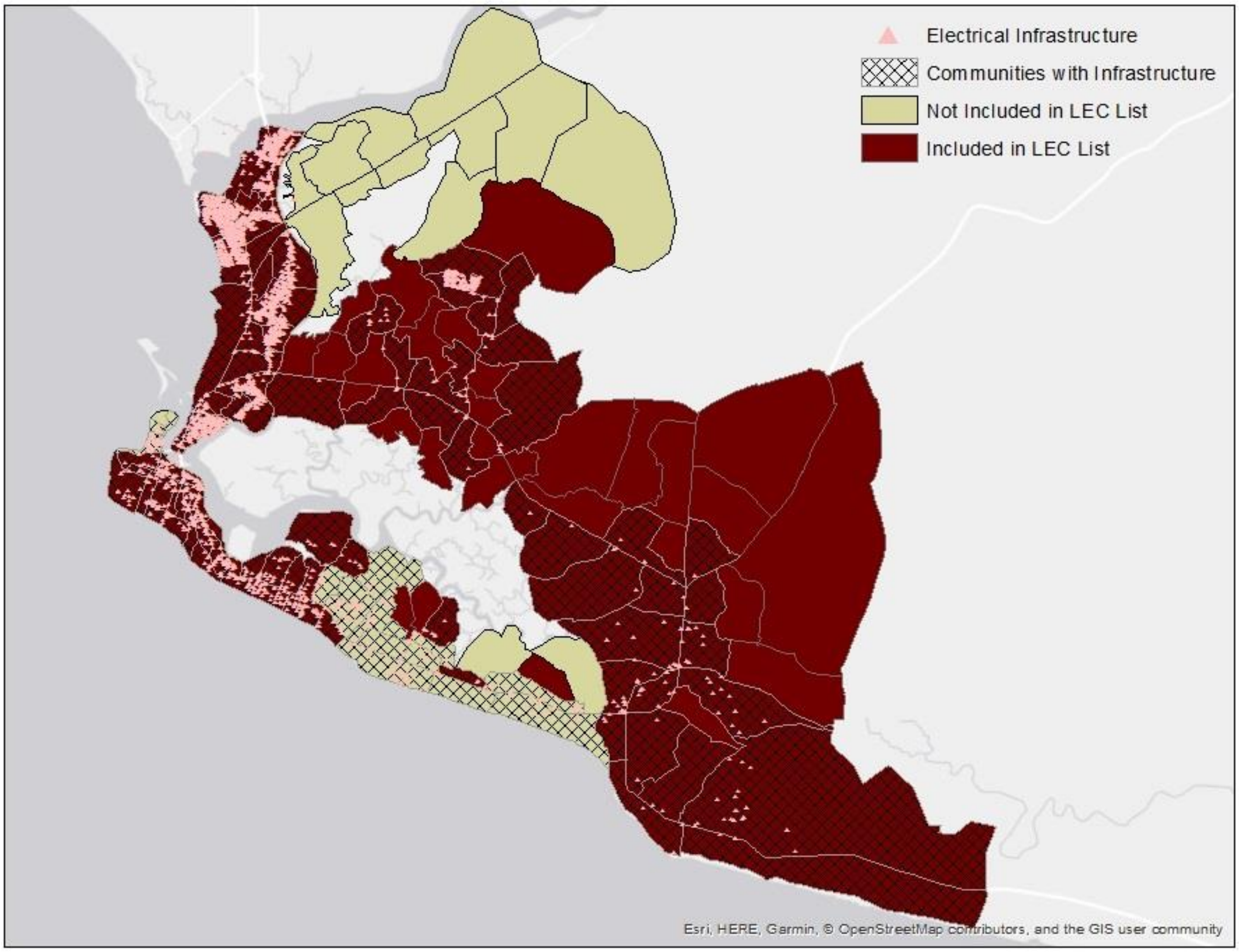
We will assess changes in key outcomes that are likely to be affected by improvements in the availability and reliability of grid electricity in several domains: energy use, education and child time use, perceptions of safety, and economic well-being, and business activities for small enterprises. These are areas in which we expect to observe measurable changes due to the compact activities, as supported by the literature on connected households and small enterprises described in Chapter II. We expect that improved quality and reliability of electricity, combined with lower tariffs and improved capacity of LEC, will lead to changes in **energy use**, including increased grid electricity use and changes in overall fuel use and appliance ownership. We will measure outcomes related to **education and child time use** because reduced outages, improved reliability, and increased electricity consumption may affect children's ability to study at night and may free up time from doing chores. However, recall information on time and energy use may not be reliable as these are difficult concepts to remember. **Perceptions of safety** may improve as become better lit at night, particularly for females. In the longer term, we could also expect to observe changes in **household economic well-being** in the form of increased consumption and income, and, potentially, property values. Further, we may see changes in mobility such that families **migrate** to be located near power lines. While we will attempt to collect information on these outcomes, recall information on them can be unreliable so we would be conservative in our interpretation of data. For small enterprises, in addition to increased electricity consumption we could also expect better quality electricity and reduced consumer costs to result in changes to **business activities**, such as hours of operation, business revenues, and number of employees.

2. Sampling and analysis

For our evaluation of *connected* households and small enterprises (small end users), we will select a sample from Monrovia and the Greater Monrovia region where most of LEC's current customers are located. We will employ a cluster sampling approach, with enumeration areas (EAs) that were used by Liberian Institute for Statistics and Geo-Information Systems (LISGIS) for the 2008 Liberian census as clusters. We will use a two-stage cluster sampling approach because LEC does not have an accurate list of its current customer base with linked addresses indicating the location of the building. The two-stage cluster sampling approach allows us to first select areas with a high concentration of current users. Next, we will conduct a listing exercise to build a sampling frame of end users. We explain this approach in detail below.

Sampling clusters with high concentration of connected end users. We will use two independent sources of information to identify clusters with high concentration of connected end users. First is a list maintained by LEC of communities that LEC currently serves in Greater Monrovia, shown in dark crimson in Figure VI.1. Second is a list of communities with at least one electricity infrastructure (including transformers, poles, fuse cutouts, etc.) according to maps assembled by USAID in 2016, shown in black cross-hatch in Figure VI.1. While we do not expect these infrastructure to align precisely to current electricity infrastructure, the fact that the communities with infrastructure generally map to the areas listed by LEC increases our confidence in the accuracy of the infrastructure map. Our first step in sampling the clusters would be to consult with MCA-L and LEC to further identify the exact communities that are currently served by LEC.

Figure VI.1. Communities Served by LEC and USAID Mapping of Electrical Infrastructure in Monrovia



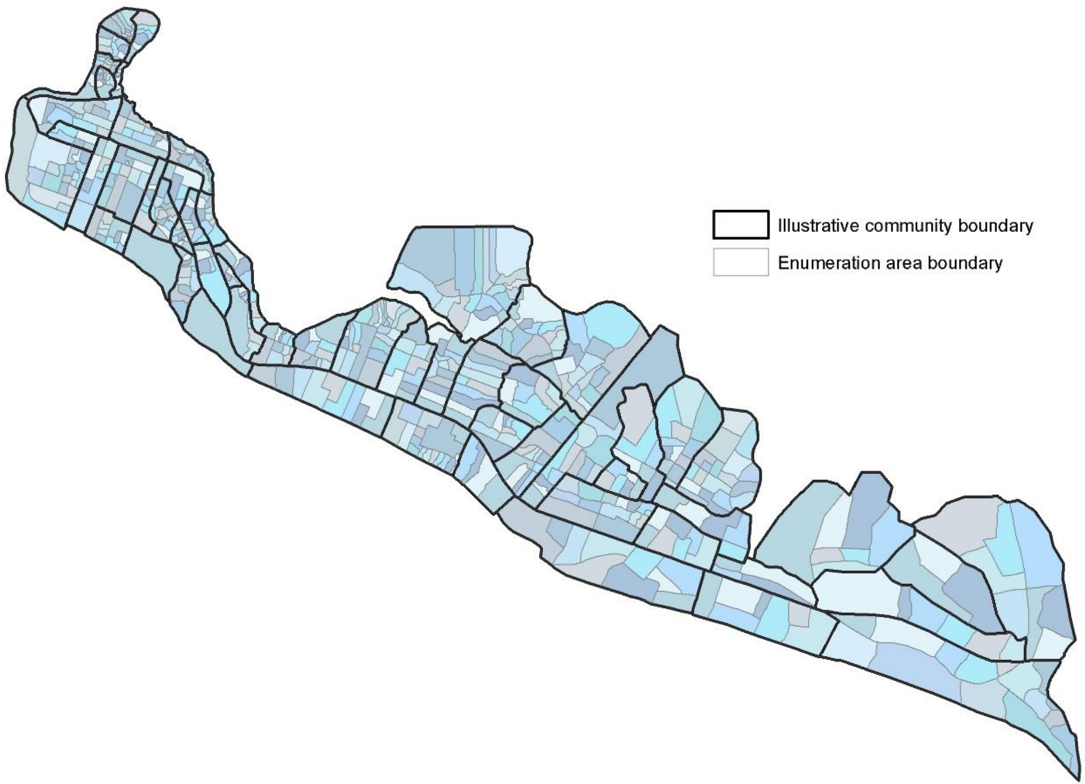
While we do not yet know the number of connected end users across these communities, we expect the LEC-served communities will include EAs from the 2008 census. In consultation with MCA-L, we will identify the EAs in the connected communities by visually inspecting the geo-referenced EA maps from LISGIS.[4] We illustrate this step in Figure VI.2, which shows illustrative community boundaries (in dark lines) in parts of Monrovia and the EAs contained in each of them (small shaded areas).[5] Once we have identified the connected communities, we will

[4] It is not necessary for the community boundaries to match exactly with the EA boundaries that fall under each connected community. We apply this step to identify smaller geographic units that are likely to have a large fraction of currently connected population.

[5] The illustrative community boundaries shown in Figure VI.1 are "clan" boundaries as defined by LISGIS for the 2008 census. The community boundaries, as defined by LEC, may not align with these clan boundaries. We will assess how closely the community boundaries align with these clan boundaries and will adjust accordingly.

proceed with the first stage of sampling and randomly select a subset of the EAs from each connected community.[6]

Figure VI.2. Illustrative cluster sampling approach for small end users



Source: Liberian Census, 2008, LISGIS.

Sampling connected end users. Next, in each of the randomly-selected EAs, we will conduct a census to list all the households and small businesses within the EA boundary. We will collect background characteristics including basic demographic information and electricity connection status. We will use this data to create two sampling frames of end users: (1) connected households and (2) connected small enterprises. We will use the sampling frames to randomly select connected households and small enterprises stratified by EAs.

To determine the sample size required for this study, we computed the minimum detectable impacts (MDIs)—the smallest impact that can be statistically distinguished from zero—for one key outcome: monthly grid electricity consumption (Table IV.3). We use the average amount of monthly grid electricity consumption of 52 kWh for connected households in Monrovia based on KPI data compiled by Tetra Tech for LEC residential customers in 2016 as the baseline average. We currently do not have information on standard deviation (SD) of average amount of monthly

[6] We will assess the feasibility of using a probability proportionate to size (PPS) sampling in the first stage to sample EAs. Ideally, in a PPS sampling strategy, clusters or EAs with a larger number of connected end users are more likely to be selected. However, our understanding is that this information is not currently available given that LEC do not have a list of their current customers that can be linked to the connected communities or EAs. We will consider the PPS sampling strategy if this information becomes available through LEC.

grid electricity consumption in Liberia. In the absence of this information, we use SD information for connected households from the MCC Tanzania Energy Project evaluation (Chaplin et al. 2017). We also present MDIs for three different sample sizes to demonstrate the size of impacts that we will be able to detect with different samples. Note that for cluster-level sampling, a higher proportion of statistical power is derived from the total number of clusters as opposed to the total number of end users. We assume an average of 50 end users for each cluster in our sample, and of these, approximately 25 will be households and 25 will be small enterprises.

We would be able to detect an increase of 9.4 kWh in grid electricity consumption, an increase of 18.1 percent from the baseline mean, for the full sample of 20 clusters and 1,000 end users. With sample size increased to 25 clusters (1,250 end users) or 30 clusters (1,500 end users), we will be able to detect smaller impacts, 8.4 kWh (16.2 percent of baseline mean) and 7.7 kWh (14.8 percent of baseline mean), respectively. These are small increases and the actual increase in electricity consumption is likely to be higher. For reference, to consume an additional 9.4 kWh of electricity per month, a household must use one additional 60W incandescent electric bulbs for about 5.5 hours each night. Also, these estimates are lower than the projected monthly increases in grid electricity consumption of around 18.82 kWh for residential T1 and D1 customers in the ERR calculations.

It is critical that we also examine detectable MDIs with a smaller subsample given that we will have both households and small enterprises in our sample. In Table VI.3, we also present MDIs for a 50 percent subsample that could represent either the household or the small enterprise sample. For the 50 percent subsample, we will be able to detect impacts of 10.0 kWh, 9.0 kWh, and 8.2 kWh with sample sizes of 500, 625, and 750 end users, respectively. The number of clusters will remain the same because we will have different types of end users, on average, in each of the clusters. These impacts are also small and are likely to be realized as connected end users will be the first to take advantage of the increased generation of grid electricity. Note that we present several scenarios for MCC to consider but we recommend the scenario to include 1,500 end users given the expectation that consumption may change only slightly, particularly among users that receive ready board connections, rather than direct connections to lines.

Table VI.3. Minimum detectable impacts for connected end users

	Sample size				
Outcome	Clusters	End users	Baseline mean	MDI	MDI (% change from mean)
Full sample					
Monthly grid electricity consumption (kWh)	30	1,500	52	7.7	14.8
	25	1,250	52	8.4	16.2
	20	1,000	52	9.4	18.1
50% sample					
Monthly grid electricity consumption (kWh)	30	750	52	8.2	15.7
	25	625	52	9.0	17.2
	20	500	52	10.0	19.2

Notes: Calculations are based on a confidence level of 95 percent, two-tailed tests, 80 percent power, 10 percent non-response rate for surveys, a pre-post correlation of 10 percent and an R-squared of 0.1. Information on baseline mean is from KPI data compiled by TetraTech for LEC residential customers in 2016. Information on baseline standard deviation are from the MCC Tanzania evaluation (Chaplin et al. 2017). kWh= Kilowatt-hour.

We will use the following linear ordinary least squares model to estimate impacts in the proposed pre-post study of connected users:

$$\text{(VI.3)} \qquad Y_{ec} = \alpha + \beta_1^{'} Post + \beta_1^{'} X_{ec} + \mu_e + \varepsilon_{ec}$$

where Y_e is the outcome of interest of end user *e* (pre or post)in community *c*; post is an indicator variable that is one if the outcome is from the post-implementation period and zero otherwise; X_{ec} is a vector of the time-variant background characteristics of end user *e* and community *c*; μ_e represent end user-level fixed effects; and ε_e is an error term. The coefficient β_1 represents the adjusted change over time in the end-user outcome.

C. Performance evaluation of medium and large businesses and public institutions

1. Approach to measuring outcomes among medium and large electricity customers

Across Greater Monrovia, medium and large end users include a mix of private enterprises and public institutions. We are aware of about 300-500 private enterprises, such as Lonestar Cell, Premier Milling, and Metalum Liberia. Public institutions include schools, hospitals, government agencies, and international organizations.[7] The economic rate of return calculations assume that an additional 1,450 enterprises will receive industrial connections. Because the improvements to electricity generation are likely to benefit most of the large electricity users and because those users are likely to be clustered in certain areas, this would lead to low power to detect impacts for any matched comparison group design. Therefore, we propose to conduct *longitudinal analyses* of electricity-related outcomes for consumers that use significantly larger amounts of electricity.

We will conduct three rounds of data collection—at baseline, interim, and final surveys—to form a panel with a broad range of outcomes. The surveys will collect information on the basic characteristics of each institution, including type; sector; year established; type of customers served; year connected to the grid; and reach (local, regional, or national). The sector will be particularly important to understand whether the business or public institution is considered energy intensive.

Table VI.4 summarizes the key outcome domains and a sample of outcomes. The domains reflect business outcomes that the literature suggests may be affected by improved electricity quality and reliability, service provision, sector functionality, and reduced tariffs. For example, we expect ***energy use and expenditures*** to change as a result of improved electricity quality and reduced outages, as well as a lower tariff. Fewer voltage fluctuations and outages may reduce ***equipment*** damage, while all aspects of a better-functioning energy sector may affect ***business productivity***.

[7] The international organizations include the World Health Organization, UNICEF, and the World Bank. We do not plan to investigate consequences of grid electricity on these types of institutions as they are less likely to be representative of medium and large businesses and public institutions in Liberia. However, we will consult with MCC if including them in our evaluation will be meaningful.

Table VI.4. Proposed outcomes for medium and large businesses and public institutions

	Sample of outcome measures	
Outcome domain	Medium and large businesses	Public institutions
Productivity	Business revenue Number of employees Hours of operation Capital investments (equipment and so on) Generator ownership	Number of employees Hours of operation Generator ownership
Energy use and expenditures	Grid and nongrid electricity use Monthly expenditures on grid electricity Monthly expenditures on nongrid electricity (such as generators and liquid fuels) Ratio of electricity costs to revenues	Grid and nongrid electricity use Monthly expenditures on grid electricity Monthly expenditures on nongrid electricity (such as generators and liquid fuels)
Equipment	Occurrence of equipment or appliance failure Cost of replacing or repairing defective equipment or appliances	Occurrence of equipment or appliance failure Cost of replacing or repairing defective equipment or appliances

We will ask survey respondents for retrospective information on all outcomes during the first round of data collection given that we are unable to conduct a pre-intervention baseline survey. We expect that the majority of medium and large businesses and public institutions will have reasonable administrative records for many outcomes, which will enable us to establish realistic baseline measures. Over the course of the study we will compare the baseline measures to interim and end-line data. We will complement these surveys with qualitative data captured through in-depth interviews with business owners and leaders in public institutions described in Section V. We will also triangulate the survey information with LEC billing data to understand the pattern of grid electricity use among the medium and large enterprises and the public institutions using grid electricity.

2. Sampling and analysis

The MCC ERR calculations and preliminary LEC administrative data suggests that there are 300-500 users in the current commercial customer base of medium and large businesses and public institutions. MCC's ERR projections suggest that this count could reach 1,400 customers. If the numbers of large end users exceed considerably by the time we conduct the baseline survey, our strategy would be to randomly sample 400-500 large end users. If we sample large end users, we will first list these customers located in Monrovia to create our sampling frame.[8] Next, we will randomly select businesses and public institutions, stratified by size, and over-sample the larger businesses and institutions. We will determine whether stratification by business or institution type will improve our ability to construct a representative sample. However, as of March 2018, the total number of commercial customers has not increased based on our conversations with LEC officials. Thus, our primary strategy for analyzing outcomes for large end users would be to survey the entire population of end users.

[8] We will explore whether this list is available from administrative sources such as the electric utility.

We do not present MDI calculations for the evaluation of large end users for two reasons. First, because we will either survey the entire population or a very large fraction of large end users, our sample will be representative of the large end users. Second, we do not have reliable baseline information on connected large end users from a comparable context for the MDI calculations. We will estimate the impact on large end users for the pre-post analysis using a similar OLS model (3) described for connected households and small enterprises.

D. Impact evaluation for unconnected end users

As noted above, the evaluation design for unconnected end users has changed. This section describes the original approach. Appendix A describes the revised evaluation design. We have developed two potential approaches to the evaluation designed to estimate impacts on unconnected households and small enterprises. Each design requires constructing a comparison group in which we contrast an intervention group of end users with grid access to a similar, but unserved comparison group without grid access. Our first approach exploits variation in natural geography to identify the impact of electrification using an instrumental variables (IV) strategy. The basic intuition is that geographical features such as land gradient may affect the placement of new grid lines, but do not necessarily affect household outcomes after accounting for baseline variables. This creates plausibly random variation in the distribution of grid lines that can be used to estimate the causal effect of electrification. Our second approach uses a matched comparison group (MCG) design, where we will create a comparison group by matching end users without grid access to an intervention group with grid access and compare outcomes between the two. We will conduct matching on a rich set of community and household characteristics that we will collect from survey data.

For both designs, we will rely on donor partners’ planned grid expansion plans to measure impacts because the donor-funded T&D infrastructure is necessary for end users to legally access the grid. We recognize that donors have faced delays in implementing their T&D plans, some of which are still in development. Subsequently, the exact location of the study will be determined based on the timing of construction of new distribution infrastructure. As we design the study, we must also take into consideration that LEC may be able to respond to the backlog of customer applications using existing infrastructure, removing some households and businesses from the pool of unconnected end users. We are actively communicating with donor partners to develop plans that leverage the opportunity of new T&D infrastructure and connections while limiting risks to the evaluation design. Although sample selection is challenging given that we must rely on others donors’ efforts, this rigorous evaluation will allow us to estimate impacts and then generalize findings to similar populations throughout Liberia.

1. Instrumental variables strategy using natural geography

Our first approach will use natural geography as a plausibly random variable in identifying the effect of grid access. We will leverage how variation in natural geography determines new T&D infrastructure installation and access to grid electricity among unserved end users. Ideally, geographical variation will allow us to identify both an intervention and comparison group of end users. The underlying assumption is that the cost and feasibility of electricity expansion varies because of natural geography and thus creates an exogenous variation in end users’ access to electricity lines. That is, as engineers determine line placement, decisions are made based on the elevation and slope of the land, rivers, soil type, and land cover and not based on economic or other differences in households or businesses. Thus geography creates similar groups that can be compared because the only differences are caused by nature. Several prior studies show that the costs of new connections and of regular access vary with the topology of each community (Lipscomb et al. 2013, Dinkelman 2011). Using this exogenous variation to explain access to grid electricity, we can estimate causal impacts by comparing end users in communities with access to grid electricity to those in otherwise similar communities without grid access due to the natural geography.

Depending on distribution line extension plans, we will implement the IV strategy in several steps, following Lipscomb et al. (2013) and Dinkelman (2011):

1. First, we will assess the feasibility of this approach by examining donor partners' T&D plans. If the distribution lines are only built along the corridors (such as within 2000 feet of the corridor), rather than constructed to extend into communities (such as more than 2000 feet), we may determine that there will not be adequate variation to use this approach.

2. Next, if we determine this approach may be feasible, we will use measures of elevation and slope from NASA's Shuttle Radar Topology Mission (SRTM), now available at 30m resolution, to estimate the probability that the electricity grid is extended to each cluster (village or community) based on these features. Other spatial data on geographic constraints like rivers, soil type, and land cover will also inform this effort. We will test the predictive power of these additional variables to determine whether they should also be included in estimating the probability that the electricity grid is extended. To estimate the probabilities, we will use the following empirical model:

   (VI.4) First stage: $Electrification_c = \mu + \nu Geophysical_c + \psi y_{0c} + \zeta X_c + \xi_c$

   where $Electrification_c$ is the binary variable denoting whether cluster c is newly electrified through the grid expansion project, $Geophysical_c$ is a vector of geophysical predictors of grid expansion for the cluster, y_{0c} is the cluster-level baseline outcome value and X_c is a vector of control variables, including distance to the nearest roads, population density, and other features of the local economy of cluster c. The predicted electrical grid expansion from the empirical model of VI.4 will serve as the first stage in our analysis, where the geophysical variable are used as instrumental variables.

3. In the next stage, we will estimate the causal impacts of electrification on the changes in end-user outcomes using the following empirical specification:

   (VI.5) Second stage: $\Delta y_{ic} = \alpha + \beta Electrification_c + \lambda y_{0ic} + \Gamma X_{ic} + \epsilon_{ic}$

   where Δy_i is the change in outcomes between baseline and follow-up for household i in cluster c, $Electrification_c$ is the predicted electric grid expansion for the cluster c, y_{0ic} is the baseline outcome for the household, and X_{ic} is a same set of control variables included in model VI.2. In estimating these specifications via two stage least squares, we will only use the portion of electrification variation predicted by geophysical characteristics, thereby avoiding selection or omitted variable bias in the relationship between grid expansion and our outcomes.

The IV approach relies on key assumptions: First, the geophysical characteristics must not be correlated with the change in outcomes over the project life, other than through their impacts on electrification. In general, responses to the geophysical characteristics are likely to be slow-moving and not correlated with the timing of the electrification project. Because we will control for baseline outcomes and examine impacts only on changes in the outcomes, this assumption is likely to hold. Moreover, because we are likely to have a number of plausible instrumental variables (slope, elevation, land cover, and other variables), we may be able to conduct overidentification tests in which we include all but one instrument in the first stage and formally assess the resulting correlation of ∂_{ic} and the excluded instrument. Second, there must be a strong first stage relationship between the geophysical characteristics and electrification. While we cannot yet assess this assumption until grid distribution expansion plans are finalized, in other settings, the slope and elevation have been important predictors of line expansion (Dinkelman 2011). On the other hand, our current understanding is that planned T&D investments follow major roads and population centers—which may suggest that geophysical characteristics will only weakly predict grid expansion and limit our ability to detect impacts along these corridors—however we are still investigating this approach as we learn more about donors' plans. Finally, this approach is only feasible if there is sufficient variation between geophysical features and our control variables, especially baseline consumption levels and distance to the nearest road. That is, we will be able to identify the effects of electrification based on geophysical features where those features do not closely correlate with roadways and communities' initial consumption.

Again, without final grid expansion plans, we cannot estimate the first stage relationship between planned electrification and geophysical features to assess the relevance assumptions. However, we conducted early analytics and found variation in the geophysical features in the three counties along the Bomi corridor (Montserrado, Gbarpolu and Bomi). We present summary statistics on SRTM-based slope and elevation which indicates that features of the terrain may play a role in the layout of the distribution grid expansion (see Table VI.5).

Table VI.5. Summary statistics of SRTM-based elevation and slope

	County		
Geographical measures	Montserrado	Gbapolu	Bomi
Elevation			
Mean	73.52	311.96	53.60
Standard Deviation	45.73	110.78	30.15
Slope			
Mean	0.71	2.03	0.64
Standard Deviation	0.57	2.08	0.49

2. Difference-in-Differences (DID) with MCG Design

If the first approach is not feasible, we propose to construct a comparison group by matching end users on community and household characteristics. We would conduct a DID analysis to estimate differences between the study groups. In a DID with a MCG design, the intervention group will be the households and small enterprises in communities with new grid access. The comparison group will be the households and small enterprises in communities without grid access, matched to the intervention communities on a host of observable community characteristics.

If we use this approach, we will implement the matching exercise in a step by step process:

1. First, using donor partner T&D maps of new distribution infrastructure, we will identify communities where lines will be placed. We will randomly select a group of these communities to include in our study sample if the number of intervention communities gaining access to the T&D network is large. Otherwise, we will include all communities gaining access. We discuss the sample size requirements in Section 4.
2. Next, we will select neighboring communities without access to the T&D network that may serve as the comparison group. We will attempt to select three comparison communities for each intervention community. The selection will be based on readily available variables such as proximity to the intervention group and population size and density.
3. Next, we will conduct a community survey in both the intervention and comparison communities selected in the previous two steps. The community survey will yield information on community characteristics such as population size, distance to nearest road, distance to nearest town, and types and materials of typical homes to assess socioeconomic status.
4. From this sampling frame, we will further match each intervention community to one comparison community on the basis of their probability of being in an area with planned grid expansion as predicted by community characteristics. This would yield a final study sample of intervention and comparison group communities. We would use a probit model to estimate the probability of being in an area with planned grid expansion based on variables collected from the community survey:

   (VI.6) $Prob\left(Electrification_c\right) = \Phi\left(\mu + \Lambda Community_e + \xi_c\right)$

   where Φ is the standard N(0,1) function. Under this method, we will choose communities with similar predicted probabilities.

5. Next we will conduct a small end user listing activity to gather basic demographic or business and electricity data from each potential end user in selected communities from the previous step. We will use this to select our sample of end users for survey data collection. We will then conduct a detailed household and small enterprise survey on these subset of users based on sample size requirements discussed on Section 4.

   Finally, in the analysis stage, we will conduct propensity score matching—this time at the end user level— to ensure balance between the selected intervention and comparison group end users. We expect this will be done separately for households and small businesses but will make this determination during the matching stage.

3. Sampling strategy

The sampling strategy for both the IV strategy and MCG design are the same. As explained in section VI.D.1, the prediction of the probability of electrification on the basis of community characteristics will serve as an important facet of the sampling strategy for communities. We will conduct a community survey that enables us to match comparison communities to intervention communities on a range of measures. We will use model VI.6 to predict the probability of a community gaining access to grid electricity and to identify intervention and comparison community pairs. This effectively trims the sample to include only the set of intervention and comparison communities whose predicted probabilities overlap. Once the study sample of communities are selected, we will conduct a listing survey or census for all households and small enterprises in each community. We will then randomly select the same fraction of end users, stratified by households and small enterprises, in each community. This will ensure our sample has an adequate representation of end users from larger communities.

4. Sample size requirement and statistical power

To determine the sample size required for this study, we computed the MDIs for one key outcome: monthly energy consumption from any source. We use this outcome as unconnected households do not consume grid electricity at baseline. As the baseline value of this outcome, we use estimates of energy consumption from any source from the 2010 World Bank willingness to pay (WTP) study that surveyed a random sample of 479 households in Monrovia without access to grid electricity. Based on this study, unconnected households consumed an average of 6.92 kWh of energy from kerosene, candles, flashlights, lamps, batteries, and other sources. This estimate is also used as the baseline amount of electricity consumption for unconnected D1 residential customers for the ERR calculations. However, we do not have SD estimates for unconnected households in Liberia. We considered using SD estimates from the MCC Tanzania Energy Project evaluation for the same outcome, which were extremely high with a coefficient of variation (SD divided by mean) of 27.5. We believe that in Liberia, where households are mostly poorer than in Tanzania, the variation in energy consumption from any sources would be much lower. Nonetheless, we present our MDI calculations for a range of COV from 2 to 15 to demonstrate how our ability to detect impacts would vary with different SD estimates.

Also, in the absence of T&D maps from the donors, we have limited ability to determine the number of communities that would gain access to grid electricity. However, we used census maps from LISGIS to estimate the number of communities that could potentially gain access to the grid along the Kakata corridor. We assumed—although can only confirm once T&D plans are finalized—that communities within an approximate 200-meter band along the Kakata corridor and within a 5-kilometer radius around Kakata city would potentially benefit from the T&D network expansion (Figure VI.3). This resulted in a total number of 125 intervention communities with grid access. Assuming equal number of 125 comparison communities, we then anticipate sampling a total of 250 communities or clusters. We also estimate MDIs for a higher alternative total sample size of 400 communities or clusters to demonstrate the sensitivity of the MDI estimates to varying cluster sample size. Finally, we also present MDIs for three different assumptions of number of households per cluster—8, 10, and 12.

Figure VI.3. Illustrative cluster sampling approach for unconnected small end users

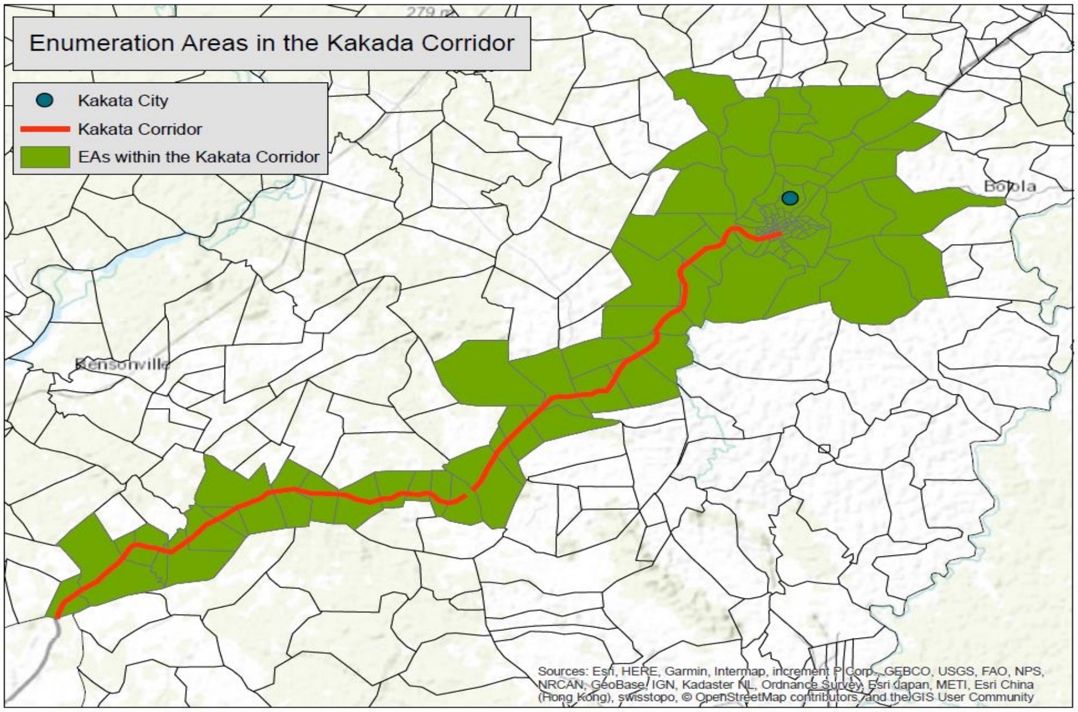
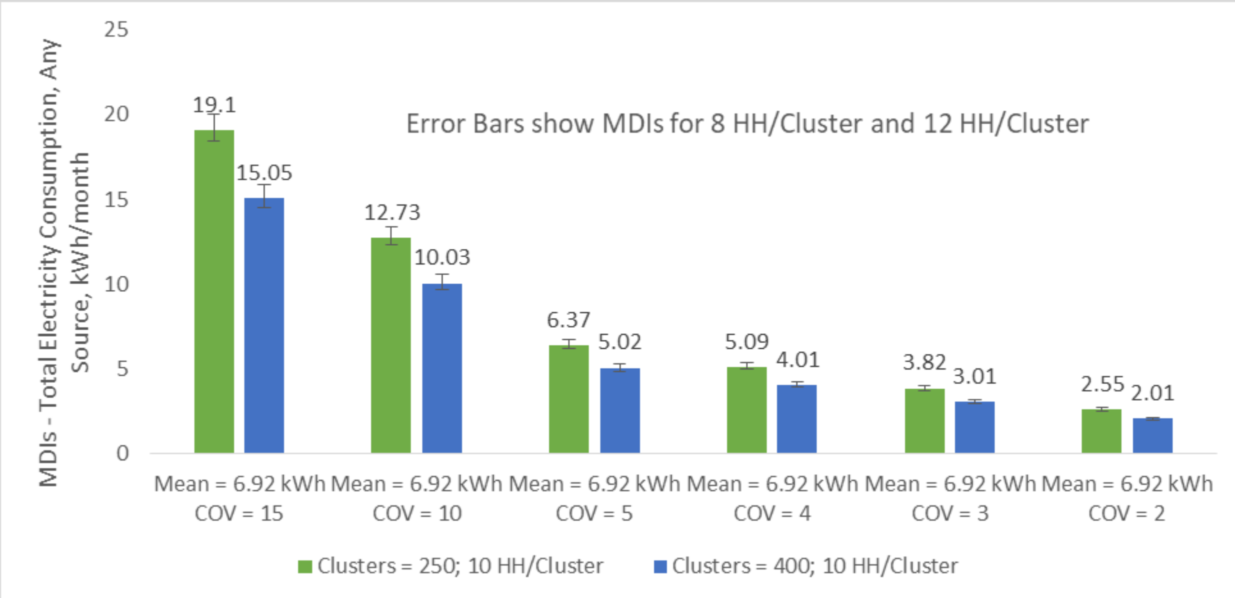


Figure VI.4 presents the MDIs for different assumptions of COV, cluster sample size, and household sample size. Each set of two columns correspond to a different COV; the green columns correspond to MDIs for a cluster sample size of 250 and the blue columns to a cluster sample size of 400; the numbers above each column represent the MDIs for 10 households per cluster for the given COV and cluster sample size assumption.

As shown in Figure VI.4, with the cluster sample size of 250 and a sample of 10 households per cluster, we would be able to detect an increase of only 2.55 kWh in electricity consumption if the COV is 2. This is shown by the green column to the far right of the figure. The MDI increases, meaning our ability to detect smaller impacts decreases, as the COV becomes larger. With the same sample sizes, we will be able to detect electricity consumption of 3.82 kWh, 5.09 kWh, 6.37 kWh, 12.73 kWh, and 19.1 kWh as the COV increases to 3, 4, 5, 10, and 15, as represented by the green columns from right to left in Figure VI.4.

Increasing the cluster sample size from 250 to 400 decreases MDIs only modestly—with a cluster sample size of 400 and 10 households per cluster—we can detect increases in electricity consumption between 2.01 kWh and 15.05 kWh as the COV ranges between 2 and 15. This is shown by the blue columns in Figure VI.4, going from right to left. Finally, varying the number of households per cluster—between 8 and 12—likewise has modest effects on MDIs as represented by the error bars above each of the columns.

Figure VI.4. Minimum detectable impacts for unconnected end users



Notes: MDI calculation is based on a confidence interval of 95 percent, two-tailed tests, 80 percent power, 10 percent non-response rate for surveys, a pre-post correlation of 10 percent and an R-squared of 0.1. Information on baseline mean is from the World Bank WTP survey of unconnected households in Monrovia.

kWh= Kilowatt-hour.

While MDIs vary widely depending on the COV, the impacts presented in Figure VI.4 are lower than the electricity consumption estimates for newly connected households assumed in the ERR calculation, suggesting that we would capture even smaller changes in consumption. In fact, average monthly electricity consumption per connection for newly connected D1 residential customers is assumed to be 24.1 kWh. However, actual increases in electricity consumption for households along the Kakata Corridor might be lower than 24.1 kWh as the ERR calculations are based on KPI data from LEC. This data is likely for Monrovia customers who may have higher rates of consumption but we will not be able to understand consumption habits until customers are connected.

We recommend a sample size of 250 clusters with 10 households per cluster, which will result in a total household sample size of 2,500. With this sample size, we will be able to detect modest changes in average monthly electricity consumption as long as the COV is within the range assumed for the calculations presented above (2-15). However, our ability to detect smaller impacts will be significantly impaired if the actual COV in Liberia is as high as the one observed in Tanzania. We will reassess sample size estimates if we obtain actual SD estimates and examine data from the first small end user study to calculate estimates among our sample.

5. Key outcomes

We will measure end user impacts across the same domains as those described for connected households and small businesses. However, we will benefit from the ability to conduct a true baseline survey and can therefore collect information on a wider range of outcomes. We will also collect information on one additional domain, ***connection rates***, which we expect to increase due to increased availability of electricity, improved T&D infrastructure, lower tariffs, and improved ability of LEC to make connections. A sample of the outcomes we plan to collect for unconnected households and small businesses are shown in Table VI.6.

Table VI.6. Outcomes, by domain, for unconnected end users

Domain (disaggregated by gender of household head or enterprise owner)	**Outcomes**
Connection rates	• Overall connection rate to grid electricity
Energy use	• Grid electricity use • Liquid fuel use • Generator ownership • Energy-intensive appliance ownership and use • Consumption of amount of light (in lumen-hours) • Cost savings
Education and child time use	• Hours children study at night • Enrollment in school • Hours doing chores
Health and safety	• Child sick in past 7 days • Adult sick in past 7 days • Perceived safety at night
Business and adult time use	• Number of income-generating activities (IGAs) • Types of IGAs • Hours of IGA operations • Paid employment • Hours worked • Hours of household chores
Economic well-being	• Household consumption • Household income and expenditures • Household assets • Property values • Poverty measures

6. Data sources

We will use a variety of administrative and primary survey data for the evaluations of end users' outcomes. The administrative data are critical to the evaluation design and sampling, whereas the primary survey data will provide information on end users' background characteristics and study outcomes. In this section, we describe the administrative data sources and the proposed primary surveys.

a. Administrative data from LEC and LISGIS

We will use information, data, and maps from LEC and LISGIS in the first stages of sampling. First, for the study of connected end users in Monrovia, we will identify areas with a high concentration of connected small end users using LEC's list of communities with a functional distribution network. Second, we will use geo-referenced maps of EAs that LISGIS used for the 2008 Liberian census to identify enumeration areas that fall under the currently connected communities. The geo-referenced EA maps will also inform the analysis of unconnected end users. Finally, for the study of medium and large businesses and public institutions, we will use a business listing from LISGIS, LEC, or the Chamber of Commerce to generate the sampling frame for the evaluation of large end users.

b. Grid expansion maps

We will use geo-referenced grid expansion maps for the corridors where T&D infrastructure will be constructed to understand the location of substations, transmission lines, transformers, and distribution lines vis-à-vis communities and potential end users. These maps will enable us to identify the intervention and comparison groups based on the catchment areas of the planned grid expansions.

c. Satellite imagery data

We will use high-resolution satellite imagery data to assess the variations in natural geography, such as topographical features. We will derive slope and elevation data from the NASA Shuttle Radar Topography Mission (SRTM), publicly available from the NASA Jet Propulsion Laboratory (http://www2.jpl.nasa.gov/srtm/). This data is retrieved from a sensor on the space shuttle Endeavor, recorded during a 11-day February 2000 mission; multiple orbits provided the ability to use radar to map the surface of the earth from multiple angles, providing enough information to calculate both elevation and derivative slope estimates. In 2015, NASA released an updated version of this data for all of Africa providing 30 meter resolution information on both slope and elevation. Accuracy for this product is variable globally, but vertical height estimates are known to be accurate within 20 meters. Please see Appendix A for an updated discussion on possible analyses using satellite imagery data.

We will use a number of primary data sources for the end user evaluations, including a community or neighborhood survey; a household and small enterprise listing; and in-person household and small business, enterprise, and public institution surveys. Table IV.7 provides a summary of these primary surveys, the sample sizes involved, the timing, and the types of information they will be designed to collect. Revised sample sizes for unconnected households and small enterprises are presented in Appendix A.

Table VI.7. Quantitative sampling and data collection for end users' outcomes (primary data sources)

Data sources	Sample size	Timing	Relevant instruments or modules
Community survey Community survey (continued)	• 30 communities in Monrovia • 500 communities total: 125 intervention and 375 comparison communities for a 1:3 ratio to improve matching in Greater Monrovia (if feasible, note until we cannot assess feasibility until we receive distribution maps)	• Baseline • Interim • Follow-up	• Community composition • Electricity access
Household and small business listing	• Households and businesses in ~30 communities in Monrovia • Households and businesses in ~500- communities in Greater Monrovia	• Baseline only	• Background characteristics • Electricity access

Data sources	Sample size	Timing	Relevant instruments or modules
Household and small enterprise survey	• 1,500 connected end users in Monrovia • 2,500 unconnected small end users in Greater Monrovia	• Baseline • Interim • Follow-up	• Electricity access • Sources and amount of energy used • Energy expenditures • Adult and child time use • Education • Health and safety • Employment • Income • Background characteristics
Enterprise survey* Public institution survey~	400-500 medium and large businesses and public institutions	• Baseline • Interim • Follow-up	• Number of employees • Electricity and other energy costs • Expenditures on generators and surge protectors • Revenue* • Service provision~

d. Community survey

We will administer a community survey at baseline, interim, and follow-up in each of the communities or neighborhoods selected for the evaluation of unserved end users. The survey obtain information on community characteristics and the potential for electricity use and enable us to improve the match of the intervention and comparison areas for the evaluation of unconnected end users. We will use the follow-up survey to estimate possible impacts on community-level outcomes such as operations of local schools and hospitals, prices of energy-related commodities such as liquid fuel, and in-migration. We will also assess non-technical losses, or energy theft, in communities to assess changes over time.

e. Household and small business listing

We will conduct a census to create a listing of all households and small businesses in each selected EA for the connected and unconnected end-user evaluations. These listings will yield data on background characteristics of end users, including their basic demographic information and electricity access or connection status. These listings will also serve as our sampling frame and will be conducted only at baseline.

f. Household and small business survey

We will collect household and small business survey data during three rounds of in-person interviews, at baseline, interim, and at follow-up to estimate the impacts of Activities 1 and 2 on end users. The surveys will collect information on electricity access, sources and amounts of energy used from different sources, and energy expenditures, including data on electricity, generators, and other electricity-intensive appliances. The surveys will include questions related to children’s time spent studying at night, enrollment in school, and perceptions of safety. To investigate the impact on the intra-household allocation of resources and gender disaggregated impacts, the surveys will ask about the amount of time adult household members use electricity, specifically, how much time women and men spend cooking and doing other household chores that require electricity within the household. We will also inquire about working for income outside of the household in positions that rely on electricity. In addition, the survey will include standard batteries of income, expenditure, and consumption questions, such as those used by the Living Standard Measurement Study to measure households' standard of living. Finally, to assess impacts on small business activities, the survey will include questions related to any income-generating activities (IGAs) households operate, including the type of the IGAs, whether owned by females, number of employees, whether the IGAs use electricity, and their revenues.

The baseline survey will yield information on key background characteristics, including the household's socioeconomic status and the gender and age of each of its members. We will use these background characteristics to create subgroups for the impact analysis and as control variables in regression models to improve the precision of the impact estimates. During the baseline survey, we will also collect geographic positioning system coordinates of the households and small businesses and contact information so we can easily find the households again at follow-up; information might include family and business contacts, current places of employment or school, and cell phone numbers.

We will survey the same set of households and small businesses at baseline, interim, and follow-up, recognizing that there will be attrition from the sample as some households will have moved out of the community. We will implement methods to reduce attrition, such as obtaining comprehensive contact information from respondents. If attrition from the sample is high, we will discuss with MCC the option of sampling a few of these mobile households for follow-up at their new locations. We may also want to consider surveying new households that moved into these communities.

g. Enterprise and public institution survey

We will administer in-person surveys for the evaluation of medium and large businesses and large public institutions. As in the household survey, the enterprise and public institution survey will measure use of grid electricity, reliability, and quality of access. The survey will gather information on the hours that a business operates and its use of electric lighting and other electrical equipment. The survey will ask about recent expenditures on capital, including electrical equipment, other equipment or machines, and repairs. To estimate workers' productivity, the survey will ask about business revenue, the number of employees, and their hours of work. Finally, the enterprise survey will collect data on the characteristics and locations of the businesses to help us to estimate impacts for different types of businesses and by community characteristics.

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VII. COST-BENEFIT ANALYSIS & BENEFICIARY ANALYSIS

The economic and beneficiary analysis of the Liberia Energy Project estimates the pre-program ERRs based on the best available parameter values related to the benefits and costs of the project. In this section, we describe MCC's pre-program ERR model, including the ERR model components and critical assumptions, and the beneficiary analysis. We then include a short discussion of our proposed approach in updating the ERRs upon the completion of the impact and performance evaluations of Activities 1 and 2. Our assessment of the ERR model and beneficiary analysis is based on the descriptions in the investment memo and the MCC ERR calculation spreadsheet.

A. Pre-intervention ERR model

The ERR is computed using the estimated economic value of total costs and the benefits of the Liberia Energy Project activities. The ERR model assumes that benefits in the form of increased electricity consumption are aggregated across all beneficiaries. These benefits will accrue to two groups to whom increased and improved-quality electricity will be made available: (1) existing customers already connected to the grid, and (2) new customers who will connect to the grid as a result of the project activities. The beneficiaries in each group include:

- D1: low-income single-phase residential customers;
- T1: medium- and high-income single-phase residential, small commercial, GoL, and nongovernmental organization (NGO) customers; Also may include three-phase residential and business customers;
- T2: three-phase commercial, GOL, and NGO customers; and
- T3: customer transformer (CT)-metered commercial and GOL customers.

For all of the beneficiaries mentioned above, the ERR model calculates the benefit over the life of the project. The benefits for all consumers and all costs are then discounted to the present. The ERR is the social discount rate (δ) at which the discounted net benefits are equal to zero. Specifically:

$$\text{(VII.1)} \qquad ERR = \delta \; at \; which \sum_{t=1}^{\tau} \frac{1}{(1+\delta)^t} NB_t = 0 \,,$$

where NB_t reflects the net benefits in year *t*, with *t* ranging from 1 to τ , the time horizon. In the MCC model, the time horizon is 20 years.

For the Liberia Energy Project, MCC calculated two versions of the ERR. Both versions have the same total estimated benefits resulting from increased consumption of electricity. However, one version includes only the costs of the Mt. Coffee Rehabilitation Activity, and the second includes this activity and the costs of the Capacity Building and Sector Reform, Mt. Coffee Support, and the LEC Training Center activities. The ERR calculations do not include the costs or benefits of the GSI investments, which are relatively small in comparison to other activities. Both versions of the ERR are estimated for five demand scenarios, depending on LEC's capacity and speed to connect customers and customer demand for connections. The estimated ERRs range between 5 and 13 percent, under different demand scenarios, when only the costs of investments in the Mt. Coffee Rehabilitation Activity are counted, and between 3 and 11 percent when costs of investments in all activities are counted. Beyond the demand scenarios, the investment memo does not provide details of a sensitivity analysis to estimate the robustness of the model. To fill this gap, MCC's ERR calculation spreadsheet includes a sensitivity analysis where the ERRs were estimated for a range of plausible values for three other parameters, including the actual MCC costs as a percentage of expected costs, the actual benefits as a percentage of actual benefits, and baseline capacity factor for unconnected large users.

1. Main components of the ERR model

The ERR model includes several benefit and cost components directly linked to the Energy Project activities, but the benefits in the ERR model are described as benefits of the Mt. Coffee Rehabilitation Activity. These benefits include two major streams directly related to the increased supply and reliability of electricity. The first is the benefit accruing to newly connected households and firms from increased electricity consumption. The second is the benefit accruing to already connected households and firms from lower expenditures on their current electricity consumption and increased consumption, both resulting from tariff reduction. Both benefit streams are calculated using a consumer surplus model, where the surplus for each consumer is based on the difference between consumers' willingness to pay (WTP) for electricity consumption and the actual price paid or the tariff rate. The overall benefit is the grand total or consumer surpluses across all existing and new consumers. The assumption is that the WTP measures how a consumer internalizes all the benefits attached to increased electricity consumption. These measures were derived from a WTP study conducted by the World Bank in 2010 that surveyed a random sample of 479 households without access to grid electricity and another 479 households connected to the electric grid in Monrovia. We discuss the reliability of this assumption in the next section.

Beyond the activity to rehabilitate Mt. Coffee, the ERR model does not include any direct benefits for the complementary investments under the Capacity Building and Sector Reform, Mt. Coffee Support, and LEC Training Center activities. The investment memo clearly discusses this omission and correctly states that the potential benefits of these complementary activities are not yet quantifiable because the activities are not all fully designed. Furthermore, we believe that many of the potential benefits of these activities will already be captured in increased consumer demand for electricity, as described in the revised program logic. For example, the Capacity Building and Sector Reform Activity will improve the overall functionality of the energy sector, including improving operations, reducing outages, and improving customer services, which will in turn lead to increased electricity consumption. Investing in strengthening LEC's capacity is necessary to increase demand for grid electricity in Liberia as current capacity is extremely low. The program logic also shows the interlinkages between the complementary activities and the Mt. Coffee Rehabilitation Activity in realizing the long-term outcomes of greater economic opportunities for households, increased business productivity, and improved capacity for public service provision. Furthermore, the LEC Training Center activity is needed to increase the number of skilled staff and improve the capacity of LEC to manage all aspects of the grid, which may lead to connecting additional customers. In contrast, the Mt. Coffee Support Activity is not necessary to realize the increased demand for electricity. However, as described in the investment memo, some of these investments are needed to mitigate adverse environmental and social effects associated with the rehabilitation of the MCHPP or to provide additional benefits to the communities surrounding the MCHPP. However, as described in the investment memo, the net benefits of this activity is unclear and thus it is reasonable to include the cost of the Mt. Coffee Support Activity with the assumption that its net benefits are negligible.

On the cost side, the two major components are MCC's and other donors' investments in the rehabilitation of MCHPP and end users' connection costs. As mentioned earlier, there are two sets of ERR calculations: one accounts for the Mt. Coffee Rehabilitation Activity costs only, and the other accounts for the costs of the Compact's four activities. However, given that all activities are necessary to achieve program goals, the version of the ERR calculation that accounts for the costs of all activities is most appropriate. While both versions also include the end users connection costs, we note that customers in Liberia currently do not pay the out-of-pocket connection fees. However, because these costs are paid indirectly by either the donor or LEC (as forgone income), they should be included in in the ERR calculation and MCC does include them.

Similarly, the pre-program ERRs depend on assumptions about demand for new connections. Specifically, the ERR calculations assume approximately 90,000 new household and commercial customer connections in the first five years of the project. Investments in the T&D system by other donors are critical to achieving this target. The costs of expansion and maintenance of the T&D network, should be reflected in the tariff rate used to calculate net benefits for the consumers. However, it is not clear whether MCC's ERR estimates reflect the costs of investments made by other donors to expand the T&D network. Specifically, the current assumptions of tariff rates between $0.26 and $0.29 seems low given the large amount of T&D investments required to connect the number of new customers forecasted in the ERR model. MCC could choose to focus on ERRs from its own perspective, including only the costs of its investments. However, if the tariff rate should reflect the full costs of T&D network expansion and maintenance, then the current estimates appear to understate the true cost of achieving a large share of the benefits incorporated in the ERR calculations.

2. Critical assumptions of the ERR model

The estimated ERRs for the Energy Project depend on the assumptions related to the benefit and cost components in the model. The investment memo describes the major assumptions of the ERR model related to the consumers' valuation of electricity consumption, price elasticity of demand, and household connection costs, such as home wiring. Assumptions are also made on the price of oil, average tariff rates, the estimated number of new grid customers, capacity factor, and generation costs. Many of these assumptions are based on Fichtner's comprehensive assessment of Liberia's energy sector (Fichtner 2014). Based on our review of the ERR assumptions, the Fichtner study, and the World Bank demand assessment study, we found the assumptions reasonable. Next, we discuss the first three critical assumptions.

Consumer WTP captures their true valuation for electricity consumption. The ERR's benefits calculations rely entirely on the willingness to pay figures derived from the World Bank survey conducted in Monrovia in 2010. Overall, MCC's calculation of increased consumption as the primary benefit of the Compact is in line with the program logic. In addition, this methodology, although data-intensive, is straightforward, and several World Bank energy projects have used WTP to calculate benefits of electrification in recent years (World Bank 2008). In these surveys, however, consumers could overstate their willingness to pay. A study in Kenya found that consumers' actual WTP for an electricity connection was far lower than their initial estimate when faced with a realistic time limit for payment (Lee et al. 2016). However, when a realistic time limit for payment was used to frame the question, the reported WTP was consistent with findings derived from varying the price experimentally. Therefore, it is important to word survey questions appropriately. Furthermore, we expect that existing customers with grid access will value more reliable electricity; however, it is not clear from the survey description if the WTP currently measures these customers' willingness to pay for higher-quality electricity. If not, future surveys should try to capture this information.

The WTP measures also do not include benefits from externalities. Consumer WTP is likely to capture their private valuation of increased electricity consumption, but it does not capture any public benefits. For example, if electricity reduces the use of traditional fuel for cooking, there might be environmental benefits (reduced external pollution). Similarly, street lighting may provide a sense of safety and security to Liberians. In addition, consumers' self-reported WTP measures are not likely to capture improved public service benefits in health and education. We recognize that the extent of these benefits is not clear and that they are difficult to measure in the short term. To the extent these benefits are realized, however, the ERRs for the Liberia Energy Project will be underestimated.

Price elasticity of demand for already connected consumers is -0.2. The ERR model assumes a low constant price elasticity of demand for existing grid customers. Therefore, it is assumed that existing customers will have a small increase in electricity consumption. This assumption is based on the literature (Bernstein and Griffin 2005; Khanna and Rao 2009). However, as the supply and reliability of electricity increases with improved customer service, the price elasticity of demand may shift upward. It is not clear how long that shift might take or whether the changes will be significant; therefore, the effects of this demand elasticity change in the future, after discounting, may not have a large effect on the benefits.

Cost of household connection is estimated at $1000 for T1 customers and $500 for D1 customers. The cost of a household connection is likely to vary by the type of household structure. For example, wiring costs can be very different for household structures made out of brick as opposed to thatch, as was found in the MCC Tanzania study (Chaplin et al. 2017). In addition, households beyond a certain distance from an electric line must pay a significantly higher cost for a connection. It is difficult to estimate connection costs for these different household structures, but a more accurate average estimate might have a large impact on the connection cost component of the ERR. For some new connections, the donor may pay connection costs, rather than the consumer, thus reducing household costs for grid connections. For example, WB contractors are installing ready boards in end users homes so that LEC is not needed to connect these households. These connection costs maybe lower if donors secure a bulk rate for connecting these end users with contractors.

B. Beneficiary analysis

The beneficiary analysis of the Energy Project links directly to the ERR model, which includes calculations of benefit streams for potential beneficiaries. The beneficiary analysis identifies who would benefit from the Energy Project, defining beneficiaries as individuals that benefit from the increased availability of electricity through the Compact activities. There are four groups of potential beneficiaries: (1) connected small end users, (2) unserved end users that may connect to the grid over the project's lifetime, (3) connected medium and large enterprises, and (4) new large customers that may connect to the grid over the project's lifetime.

In households, both connected and potential new customers, all members of the household are counted as beneficiaries. MCC expects that 90,000 new residential connections (D1 and T1) will be made in addition to 12,900 existing connections, for a total number of 102,900 connected households in the first five years of the project.[9] MCC also expects that 15 percent of the 162 large user connections will be residential. Assuming an average household size of 5.1, this will result in a total of 524,914 beneficiaries.[10]

MCC also expects a total of 1,450 commercial (T2) connections and 162 industrial (T3) connections over the first three years of the project. We understand that, for already connected firms, only the owner was counted as the beneficiary but then was removed because it was assumed that the owner was already counted as a residential beneficiary. Although these firms are projected to benefit from the increased consumption of electricity, MCC correctly points out that it is not clear whether that benefit would result in increases in employee wages or additional employment because of Liberia's high unemployment rate. For new commercial and industrial connections, the investment memo indicates that all expected employees of these firms, based on expected firm size, and all household members of these expected employees, based on average household size of 5.1, are counted as beneficiaries. However, many of these potential employees will likely already belong to a connected household. Most of the new commercial and industrial connections are expected in Greater Monrovia, and most of the potential employees are also likely to reside in Greater Monrovia. Therefore, there is a high likelihood of double counting these beneficiaries.

The beneficiary analysis in the investment memo does not discuss the expected distribution of impacts by household characteristics or the household head's age, gender, and socioeconomic status. Furthermore, impacts will likely vary by localities. Those living near an existing or newly built electric grid line are expected to experience the greatest improvement in service because of increased generation and a new or improved distribution system. The beneficiary analysis also does not examine how benefits to firms would be spread across informal and formal businesses and small, medium, and large businesses.

[9] These estimates are from the ERR calculation spreadsheet.

[10] The numbers of beneficiaries reported in the investment memo and in the ERR calculation spreadsheet are inconsistent. The investment memo reports a beneficiary count of 460,534, which seems to be based on the number of new connections. We apply the beneficiary count in the ERR calculation spreadsheet as the correct one because it is in line with the descriptions in the investment memo and the supporting notes in the ERR calculation spreadsheet.

Finally, the beneficiary analysis only counts individuals or businesses that would connect to the grid. According to the logic model in Figure II.1, public service institutes such as education and health facilities would also benefit from the Energy Project, and a long-term benefit of the project may be the government's improved capacity for public service provision. If some public service facilities are located in areas where not all individuals who might benefit from their improved services are connected, there could be unconnected beneficiaries of the Energy Project. However, it might be challenging to capture benefits related to improvements in the quality of social services.

C. Plan for assessing the ERR assumptions and parameters and recalculating if warranted

The proposed impact and performance evaluations will enable us to assess the main assumptions underlying the CBA model for the Liberia Energy Project and update the model to provide useful lessons for future energy projects. Our approach to updating the ERR calculations involves revising both the cost and the benefit estimates, along with the assumptions, to the extent feasible. Although the impact and performance evaluations are designed to give us updated information on some of the parameters and assumptions related to the benefit calculations, it is important to update the cost information, too. This update is specifically important in the context of the Liberian Energy Project because the large increases in customer base from which most of the benefits of the project will derive is dependent on T&D investment from other donors. In updating the cost estimate for the Evaluation-Based ERR calculation, we will attempt to include the costs of these other donor investments. On the benefits side, our approach will be to reassess the ERR assumptions and the parameters using the results from our impact and performance evaluations. In Table VII.1, we discuss the feasibility of updating relevant assumptions and parameters. Please refer to Appendix A for notes on how the revised evaluation design will affect our ability to update the parameters in the CBA and ERR model.

Table VII.1. ERR parameters and measurement

ERR parameters	Measurement
Demand for new connections	Administrative data on new connections and the impact evaluation for unconnected end users will examine the impact of the MCHPP rehabilitation on connection rates as one of the main research outcomes.
Increase in demand for already connected consumers	The evaluation for already connected end users will be able to quantify increased demand for already connected households.
Consumer willingness to pay	As part of our evaluation, we will examine data from the updated WTP survey to update at least some of the WTP estimates. We will look into the possibility of adding or modifying the framing of some existing questions to elicit better information on customer WTP.
Tariff	The tariff is expected to change as a result of the Capacity Building and Sector Reform Activity. We will better understand the tariff structure from our interviews with key stakeholders and document reviews. We will also use information from the cost of service studies to examine whether the tariff rates used in the ERR calculations are cost reflective and whether they need to be updated.
Electricity generation costs	We also will gather information on generation costs for MCHPP.

ERR parameters	Measurement
Technical losses in the distribution network	Our quantitative performance evaluation of grid-level outcomes is designed to measure technical losses using data from the SCADA system expected to be funded and installed with support from the World Bank. Although MCHPP is equipped with a SCADA system that electronically generates real-time data, no comparable system exists for the rest of the network. Furthermore, the World Bank system will not cover all substations in Monrovia.
Cost of household connection	We will gather information on connection costs for each type of connection from our survey of different types of end users to assess whether the assumptions made in the ERR model need to be updated. The household and small-enterprise surveys will provide information on residential T1 and D1 customers. The large-enterprise survey will provide information on commercial (T2) and industrial (T3) customers. We will also try to assess whether and to what extent true cost of connecting (wiring plus connection fee) varies by different types of households and businesses.
Beneficiary population	The impact evaluation will provide data on the distribution of benefits of increased electricity supply and reliability across the population and for different subgroups.

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VIII. DATA COLLECTION

As described, we will collect existing administrative and primary data, as well as documentation, from numerous sources to answer the research questions throughout the course of the evaluation. In the next section, we describe our instrument development and data collection approach, as well as how we ensure high quality data collection. We also present an overview of data collection training and data processing practices.

A. Local data collection partners

We will initiate a competitive process to identify a local data collection partner for the quantitative and qualitative data collection activities. The competitive procurement will help identify high-quality data collection firms while ensuring competitive costs. The selection of the firms will depend on the capabilities and cost of the firms that respond to the call for proposals, including their experience, expertise, and capacity to meet the needs of our data collection effort. We expect the same firm conducting the quantitative data collection will also conduct the qualitative data collection.

B. Approach to collecting high quality data

The evaluation's success depends on the collection of high quality data, particularly the accuracy, reliability, and timeliness of the data. We will actively anticipate risks and minimize threats to quality that are inherent in the data collection process. Prior to undertaking any data collection efforts, we will provide detailed data collection plans, safety measures, and procedures for obtaining all necessary permissions from local authorities. We will submit these to MCC and MCA-Liberia for approval prior to any fieldwork. Survey instruments and protocols will also be submitted for review and input from MCC, MCA-L, and possible additional stakeholders.

We will ensure high quality data by providing thorough and consistent oversight on all aspects of the data collection process. Due to the limited technical capacity available in Liberia, Mathematica anticipates a greater-than-normal level of involvement in the training and oversight of the data collection efforts. We will work closely with the local data collection firm and oversee all their efforts, from identifying and training enumerators to developing teams, conducting interviews, transcribing and translating, preliminary coding, and submitting data for analysis. Mathematica and the local data collector may conduct some of the high-level interviews jointly. To ensure that protocols are properly followed, Mathematica will conduct interviewer observations and attend interviewer debriefings.

In addition to overseeing data collection, we will develop and test all qualitative and quantitative instruments. For qualitative approaches, we will develop tailored protocols for each round of data collection. The protocols will cover similar themes across respondents to facilitate triangulation of responses. For the quantitative data, we propose using a computer-assisted personal interviewing (CAPI) system on tablets, such as the Survey Solutions platform developed by the World Bank, which would enable us to review the data and conduct consistency checks on an ongoing basis. The system is designed to work in low-resource countries by operating with a user-friendly format on a variety of tablets. A CAPI system greatly increases data quality by controlling the skip pattern, removing the need for data entry, and reducing survey administration time. The program is also password-protected, and once synchronized, the data are uploaded to a cloud server and not stored on the tablet, increasing data security and protection of PIIs in case of loss or theft of the tablet.

C. Data collection training

Mathematica evaluation team members will travel to Liberia for training, pre-testing of survey instruments and protocols, and field observations for each data collection round. For qualitative interviews, Mathematica may conduct some interviews jointly with the local firm for interviews with high-level stakeholders. The local data collection firm will transcribe the interviews and provide verbatim translations when necessary. The firm will also clean the data, which will include reviewing transcripts for fidelity to the recordings, adding definitions of acronyms and jargon, and adding notes for context.

Prior to the fieldwork, we will conduct pre-tests to assess whether respondents can interpret the items as intended, whether the answer options are appropriate, and whether there is variation in responses. Mathematica will participate jointly with our local partners to train interviewers and monitor the data collection effort. We will put in place data collection and data entry procedures to minimize risks to data quality. For qualitative data, we will follow best practices to minimize any risk, including recording, transcribing, and translating (verbatim) all interviews so the analysis can be done using the raw data rather than notes taken during the session. We will also adapt the survey instruments and protocols based on what is being learned in the field, when appropriate, and regularly review data to ensure that they are internally consistent and that they meet our rigorous quality standards.

D. Timing of data collection activities

We will collect qualitative and quantitative data in a manner that maximizes efficiency and minimizes costs. First, as stated, the implementation and performance analyses will be conducted in an ongoing, iterative process that reflects program implementation, as opposed to a limited schedule of traditional data collection cycles that can miss key events, processes, and milestones. We anticipate collecting data on the following schedule:

- Administrative data (when they become available) on a quarterly basis
- Documentation on an ongoing, rolling basis as key materials become available
- Key informant interviews at project initiation and annually thereafter, or on an as-needed basis, either in person or by telephone
- Stakeholder interviews with businesses and focus group discussions with household members at three time points, aligned with quantitative data collection
- Site visits at three time points, aligned with quantitative data collection

The timing, along with the sample sizes and key instruments/modules for qualitative and quantitative data collection activities are summarized in Table VIII.1 and Table VIII.2, respectively. We also indicate the exposure periods, which we define as the estimated number of months required for the intervention to produce the expected improvements on listed outcomes. Please see Appendix A for updates to the timing of data collection for unconnected households and small enterprises.

Table VIII.1. Qualitative data collection summary

Data collection	Timing (include multiple rounds)	Sample Unit / Respondent	Sample Size	Relevant instruments/ modules (Abbreviated from Tables IV.2 and V.2)	Exposure Period (Identified in months as feasible)
Document review	Regularly throughout evaluation	N/A	N/A	• Grid-level and infrastructure changes • Tracking of laws, policies, regulations • Tracking of energy production • LERC documentation • Identification of modernization processes affecting market structure, and sector governance and performance • Documentation of how Activities 1 and 2 have affected new connections and energy consumption in Greater Monrovia • Documentation of the MSC's efforts to strengthen LEC's capacity	The exposure period between intervention and observable outcomes will vary based on the activity and outcomes of interest. For example, we estimate an exposure period of: • 12 months to 3 years for infrastructure changes to be operational and observable • 24 months for the LERC to become operational and influence laws, policies, and regulations • 36 months for the LERC and greater energy production to influence measurable changes in the market structure • 12-36 months from when MCHHP produced high quality electricity for end user consumption to measureably change • 6-12 months from when the MSC is operational for changes in LEC's capacity to be measureable Note that we began reviewing documents for the EA report in 2017 and will continue to review documentation throughout the evaluation and post Compact so that we can assess changes in outcomes over time and based on implementation. We expect to formalize the document review process in September 2018 as we develop the full conceptual map and refine tools that guide the document review process.

Data collection	Timing (include multiple rounds)	Sample Unit / Respondent	Sample Size	Relevant instruments/ modules (Abbreviated from Tables IV.2 and V.2)	Exposure Period (Identified in months as feasible)
Interviews with key informants and stakeholders *Conducted by Mathematica	10/2018 and annually thereafter, or more often if needed based on key milestones and events	MCHPP MME and LERC LEC, MSC, CMC MCA, EU, KfW, NORAD, Power Africa, and the World Bank	2 4-6 4-6 6-10	**Implementation**: • Compact design, planning, execution, and sustainability • Implementation of each activity and sub-activity, including SWOT analysis • Perceptions of LEC and LERC functioning • Overall donor coordination and SWOT analysis of multiple donor model • Assessment of and challenges to sustainability of Compact investments **Grid outcomes:** • Perceptions of changes in electricity production, T&D, and consumption	We expect implementation outcomes to begin materializing in 2018 with the month varying depending on activity. For example, we estimate an exposure period of: • 6-12 months from when the MSC is operational for changes in LEC's capacity to be measureable. Note that the MSC became operational in January 2018. • 36 months for the LERC and greater energy production to influence measurable changes in the market structure. We note that the exposure time between MME and LERC activities and outcomes depends upon government appointments and staffing but we expect a longer interval given the nature of their activities. We will keep abreast of activities to determine the most appropriate time to conduct interviews. We aim to follow progress regularly throughout the evaluation.

Data collection	Timing (include multiple rounds)	Sample Unit / Respondent	Sample Size	Relevant instruments/ modules (Abbreviated from Tables IV.2 and V.2)	Exposure Period (Identified in months as feasible)
Interviews with key informants and stakeholders *Conducted by Mathematica (continued)	10/2018 and annually thereafter, or more often if needed based on key milestones and events (continued)	IPPs, CIE	4-6	• Contribution and SWOT analysis of capacity strengthening and sector reform activities **Energy sector outcomes:** • Perceptions of LERC's independence and accountability; energy sector progress and constraints; and energy policies, laws, and regulations • IPP's experience with power production and sales and IPP survivability **Utility outcomes:** • Perceptions of LEC and MSC • Perceptions of the sustainability of plans, processes, data, and other systems	For grid outcomes, we estimate an exposure period of: • 12 months to 3 years for infrastructure changes to be operational and observable. Note that MCC funded grid level outcomes should be completed by 2018 however additional investments have been made by MCA for LEC materials so that changes may continue throughout the Compact. We began tracking these outcomes in 2018, with retrospective data for 2017, and will conduct relevant interviews throughout the evaluation. For energy sector, we estimate an exposure period of: • 12 to 48 months depending upon government appointments to the MME and the pace of new power generation (including the CLSG line) and T&D infrastructure construction, each of which will place more urgency on energy sector modernization. LERC's operations will also impact the time it takes for there to be measurable changes in the energy sector, through the establishment of laws, policies, and regulations For energy utility outcomes, we estimate an exposure period of: • 6-12 months from when the MSC is operational for changes in the utility's plans, processes, and systems to be measureable • 12-24 months for perceptions of LEC to change We will continue to check in with stakeholders and conduct interviews as implementation progresses.

Data collection	Timing (include multiple rounds)	Sample Unit / Respondent	Sample Size	Relevant instruments/ modules (Abbreviated from Tables IV.2 and V.2)	Exposure Period (Identified in months as feasible)
Interviews with end-users Focus group discussions with end-users	Baseline: 6/2019-8/2019 Interim: 10/2020-12/2020 Follow-up: 10/2023-12/2023	Enterprises of various sizes Public sector Households and small enterprises	10 10 10, with 8-10 FGD participants	**End user outcomes:** • Connection decisions, cost, process, and barriers to connecting • Perceptions of electricity quality, reliability, and affordability • Energy-related behaviors, such as changes in energy consumption and use of other energy sources • Based on grid connection, changes in business or service provision, use or purchase of equipment or appliances, changes in inventory, sales, revenue, profit, productivity, workforce size or composition • Consumption uses, and new purchases and services • Productivity and time use • Spillover effects	For end user outcomes to emerge, we estimate an exposure period of: • 12-24 months from when customers are connected or receive MCHPP electricity for measureable outcomes to emerge depending on the outcome. For example • 12 months from connecting, there may be measurable changes in energy consumption • 12 months from connecting, there may be measureable changes in behavior related to electricity usage • 24 to 48 months from connecting, there may be measureable changes in income • 24 to 48 months from connecting, there may be measureable changes in appliance purchases or usage Our data collection timeline aims to maximize the chances of observing outcomes among the largest share of the end user sample. Please note the variability in the connection dates such that the time between exposure and outcomes may only be months for some customers but years for others because connections happen on a rolling basis. Interim data collection is scheduled for 2020 to maximize the chance of observing outcomes across the sample of end users. We are tracking infrastructure improvements with LEC and donor partners.

Data collection	Timing (include multiple rounds)	Sample Unit / Respondent	Sample Size	Relevant instruments/ modules (Abbreviated from Tables IV.2 and V.2)	Exposure Period (Identified in months as feasible)
Site visits	Baseline: 9/2018-12/2018 Interim: 10/2020-12/2020 Follow-up: 10/2023-12/2023	MCHPP and substations T&D infrastructure	TBD	• Operational processes and systems • Procedures to handle equipment failure, • Use of data management systems and communication procedures • Functionality of infrastructure	Again, for infrastructure related outcomes, we estimate an exposure period of: • 12 months to 3 years for infrastructure changes to be operational and observable. Note that MCC funded grid level outcomes should be completed by 2018 however additional investments have been made by MCA for LEC materials so that changes may continue throughout the Compact. We have conducted several site visits during the project launch and in September 2018. Also, for utility related outcomes, we estimate an exposure period of: • 6-12 months from when the MSC is operational for changes in the utility’s plans, processes, and systems to be measureable

Table VIII.2. Quantitative data collection summary

Data collection	Timing MM/YYYY	Sample Unit/ Respondent	Sample Size	Relevant instruments/ modules	Exposure Period (months) (Identified in months as feasible)
Administrative data from LEC, LERC, MME	Monthly	N/A	N/A	• Grid outcomes such as electricity production, voltage stability, peak demand shortage, technical losses, and number of customers • Energy sector outcomes such as cost recovery rates; number, size, and type of IPPs, and tariffs across user types • End-user outcomes such as number of applications, wait time for connection, and customer satisfaction with LEC • Utility outcomes such as technical and financial efficiency, staff productivity and retention, collection rates, and energy forecasts	The quantitative data collection will focus on both administrative date that measures changes at the level of the utility and energy sector, as well as field data collection that focuses on measuring outcomes among end users Again, for utility related outcomes, we estimate an exposure period of: • 6-12 months from when the MSC is operational for changes in the utility's plans, processes, and systems to be measureable and for changes in generation, transmission, the number of customers and customer consumption, and electricity reliability and quality.
Small end user listing (households and small businesses)	Baseline: 10/2018	Connected EAs (communities) in Monrovia Unconnected communities in Greater Monrovia	All households / businesses in 30 EAs All households / businesses in ~500 communities (if it is feasible to select 1:3 ratio of comparison communities	• Background characteristics • Electricity access	For end user outcomes to emerge, we estimate the exposure period will vary by outcome (as describe above) an may vary from: • 12 to 24 months from when customers are connected or receive MCHPP electricity for measureable outcomes to emerge such as in consumption, energy related rebahviors, time use, appliance ownership and usage. • 12 to 24 months from when customers are connected or receive MCHPP electricity for measureable outcomes to emerge at the community level such as changes in markets, safety, the number of households or households moving into a connected area.

<table>
<thead>
<tr><th>Data collection</th><th>Timing MM/YYYY</th><th>Sample Unit/ Respondent</th><th>Sample Size</th><th>Relevant instruments/ modules</th><th>Exposure Period (months) (Identified in months as feasible)</th></tr>
</thead>
<tbody>
<tr><td rowspan="2">Community survey</td><td rowspan="2">Baseline: 10/2018

Interim: 10/2020-12/2020

Follow-up: 10/2023</td><td>Connected end users in Monrovia</td><td>30</td><td rowspan="2">• Community composition
• Electricity access</td><td rowspan="2">• 12 to 24 months from when customers are connected or receive MCHPP electricity for measureable outcomes to emerge among small, medium, or large businesses, such as changes in production, sales, operating hours, the number of employees and other outcomes.
We aim to collect both retrospective and prospective data to capture outcomes that appear prior to the evaluation activities commence.</td></tr>
<tr><td>Unconnected small end users in Greater Monrovia</td><td>500 communities (125 intervention and 375 comparison)</td></tr>
<tr><td>Household and small enterprise survey</td><td>Baseline: 11/2018-12/2018

Interim: 10/2020-12/2020

Follow-up: 10/2023-12/2023</td><td>Connected small end users in Monrovia
Unconnected small end users in Greater Monrovia</td><td>1,500

2,500</td><td>• Electricity access
• Sources and amount of energy used
• Energy expenditures
• Adult and child time use
• Education
• Health and safety
• Income, employment
• Background characteristics</td><td rowspan="2">For end user outcomes to emerge, we estimate the exposure period will vary by outcome (as describe above) and may vary from:
• 12 to 24 months from when customers are connected or receive MCHPP electricity for measureable outcomes to emerge such as in consumption, energy related rebahviors, time use, appliance ownership and usage.
• 12 to 24 months from when customers are connected or receive MCHPP electricity for measureable outcomes to emerge at the community level such as changes in markets, safety, the number of households or households moving into a connected area.
• 12 to 24 months from when customers are connected or receive MCHPP electricity for measureable outcomes to emerge among small, medium, or large businesses, such as changes in production, sales, operating hours, the number of employees and other outcomes.
We aim to collect both retrospective and prospective data to capture outcomes that appear prior to the evaluation activities commence.</td></tr>
<tr><td>Enterprise survey

Public institution survey</td><td>Baseline: 7/2019-9/2019

Interim: 10/2020-12/2020

Follow-up: 10/2023-12/2023</td><td>Medium and large businesses and public institutions in Monrovia</td><td>400-500</td><td>• Number of employees
• Electricity and other energy costs
• Expenditures on generators and surge protectors
• Revenue
• Service provision</td></tr>
</tbody>
</table>

For the impact evaluation, we plan to conduct baseline data collection in autumn 2018 for connected households in Monrovia and hopefully among unconnected households in Greater Monrovia, prior to the grid expansion. This schedule of sequential data collection will allow us to first launch the study of connected households in Monrovia as soon as possible and also collect measures among unconnected households in Greater Monrovia before users are able to take advantage of new connections. We will conduct an interim data collection after the grid expansion has taken place and households and businesses have the ability to establish new connections, before the Compact ends. The interim round of data collection will allow us to collect information on short- to medium-term outcomes. Data from multiple rounds is critical to validating and improving confidence in findings across the collection activities, identifying important areas of inquiry that may not be evident from the outset, an, and assessing the likelihood of observing longer-term impacts. Further, collecting data collection prior to the Compact end will also allow us to interview key actors involved in the implementation of the Compact activities. End line data collection will take place a few years later, prior to the end of the contract, to assess long-term impacts. The end line data will also allow us to calculate the rate of connectivity for households and businesses once the availability of electricity has been established, as well as finalize the ERR. We anticipate the end line to take place in the last quarter of 2023. See Appendix A for updates to the anticipated timeline of data collection for the unconnected study.

IX. ADMINISTRATIVE ISSUES

We will carefully manage this complex and multicomponent evaluation. Next, we describe administrative issues relevant to conducting the evaluation and present a timeline for evaluation activities.

A. Summary of IRB requirements and clearances

Mathematica is committed to protecting the rights and welfare of human subjects by obtaining approval from an IRB for relevant research and data collection activities. IRB approval requires three sets of documents: (1) a research protocol, in which we describe the purpose and design of the research, and provide information about our plans for protecting study participants, their confidentiality and human rights, including how we will acquire consent for their participation; (2) copies of all data collection instruments and consent forms that we plan to use for the evaluation; and (3) a completed IRB questionnaire that provides information about the research protocol, how we will securely collect and store our data, our plans for protecting participants' rights, and any possible threats to participants resulting from any compromise of data confidentiality. We anticipate the IRB review of this study to qualify for expedited review because it presents minimal risk to participants. IRB approval is valid for one year; we will submit annual renewals for approvals for subsequent years as needed.

We will also ensure that the study meets all U.S. and local research standards for ethical clearance, including submitting our study for approval by Liberia's ethical review committee. We will coordinate with our consultant and data collection partner to submit the full list of required materials, including a description of the methodology, the instruments and enumerator manuals, a community awareness plan, the timeline, budget, and a dissemination plan, to the required local agency. Mathematica may request support from MCA-Liberia to facilitate the process. If either the U.S. IRB or local authorities recommends changes to protocols or instruments, the survey firm, MCC, and Mathematica will work together to accommodate the changes, and all parties will agree on the final protocol before data collection begins.

B. Data access, privacy, and file preparation

All data collected for this evaluation will be securely transferred from the data collection firm to Mathematica, will be stored on Mathematica's secure server and will be accessible only to project team members who use the data. After producing and finalizing each of the final evaluation reports, we will prepare corresponding de-identified data files, user manuals, and codebooks based on the quantitative survey data. We understand that these files could be made available to the public; therefore, the data files, user manuals, and codebooks will be de-identified according to MCC's most recent guidelines. Public use data files will be free of personal or geographic identifiers that would permit unassisted identification of individual respondents or their households, and we will remove or adjust variables that introduce reasonable risks of deductive disclosure of the identity of individual participants. We will also recode unique and rare data by using top and bottom coding or replacing these observations with missing values. If necessary, we will also collapse any variables that make an individual highly visible because of geographic or other factors into less easily identifiable categories.

C. Dissemination plan

To ensure that the results and lessons from the evaluation reach a wide audience, we will work with MCC to increase the visibility of the evaluation and findings targeted to the energy sector, particularly for policymakers and practitioners. We will present findings from each round of data collection in baseline, interim, and final evaluation reports. We will distribute draft reports to stakeholders for feedback before finalization and will present findings at MCC headquarters in Washington, DC and MCA-Liberia headquarters.

We expect the broader research community to have a strong interest in the findings from the evaluation. To facilitate wider dissemination of findings and lessons learned, we will collaborate with MCC and other stakeholders to identify additional forums—conferences, workshops, and publications—for disseminating the results and encourage other donors and implementers to integrate the findings into their programming.

D. Evaluation team: Roles and responsibilities

Our team will contribute our extensive experience and expertise to meet MCC's evaluation needs. Program manager **Dr. Candace Miller** will be responsible for managing the team of experts and delivering high quality products to MCC. **Dr. Ali Protik** and **Mr. Randall Blair** will serve as co-evaluation experts, leading the design and implementation of the quantitative and qualitative evaluations, respectively. **Mr. Denzel Hankinson** and **Mr. Gerald Coleman** will serve as co-energy experts for the evaluation. Mr. Hankinson will provide energy data modeling expertise while Mr. Coleman, a Liberian energy expert, will provide contextual information, expertise in using utility data, including SAIDI/SAIFI, voltage quality, and blackouts to inform the evaluation design. **Ms. Kristine Bos** will support the collection of high quality data and analysis. **Dr. Arif Mamun** will provide quality assurance on all deliverables.

E. Evaluation timeline and reporting schedule

The evaluation activities will be ongoing over the course of the evaluation, as described in Chapter VIII. Administrative data and documentation will be collected on a regular basis, while key informant interviews will be conducted annually or on an as-needed basis. Interviews with businesses, focus group discussions with households, and site visits will be concentrated around the baseline, interim, and endline quantitative data collection efforts (Table IX.1, Figure IX.1). We expect that baseline data collection will occur in autumn 2018; interim data collection in late 2020, prior to Compact close; and endline data collection at the end of 2023. We note that the timeline could change as compact implementation evolves and is based on several research-based principles: First, we aim to collect pre-intervention data to understand outcomes prior to implementation. When baseline data is not feasible because activities were underway prior to EDR approval, we aim to collect retrospective data. The baseline information will enable us to measure change over time which can be attributed or linked to MCC's investments. Next, we aim to collect interim data to understand implementation and performance as the project evolves and the Liberian context changes and impact data to understand end user impacts. We will collect administrative data, documentation, and other qualitative data on a rolling basis throughout the energy evaluation to keep abreast of changes as they occur. We will conduct quantitative and qualitative end user interim data collection in 2020 because experience and similar energy studies confirm that outcomes—such as changes in end users' economic situation and behaviors—emerge after users are actually connected and have at least a couple years of connectivity. Finally, we propose endline data collection for end users in 2023 to maximize the chances that we will capture the longer term outcomes that take years of connectivity to emerge, such as acquiring time saving appliances, increased employment, and other business expansion.

Table IX.1. Evaluation timeline and reporting schedule

Name of Round	Data Collection	Data Cleaning & Analysis	First Draft Report Expected	Final Draft Report Expected
Baseline	September 2018 - August 2019	January-September 2019	October 2019	December 2019
Interim	October-December 2020	January-March 2021	April 2021	July 2021
Endline	October-December 2023	January-April 2024	June 2024	January 2025

Mathematica will produce written reports following each round of quantitative data collection. Contingent upon the schedule of compact implementation, the baseline report is expected in the fourth quarter of 2019, the interim report in the third quarter of 2021, and the final evaluation report in early 2025. Mathematica expects to complete all scheduled tasks within the eight-year period.

Figure IX.1. Project schedule for the evaluation

Table X.X Project schedule for the evaluation

Period of performance	Option Period 1						Option Period 2							Option Period 3															
Calendar year	2018			2019				2020				2021				2022				2023				2024				2025	
Quarter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Task																													
1. Administrative data collection from LEC, MSC, LERC			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—						
2. Documentation review (on-going basis)			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—						
3. Key informatnt interviews and conversations (annual or as needed)			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—						
4. Site Visits			□					□				E											□						
5. Develop baseline evaluation materials												s																	
Data collection firm TORs	▲											t																	
Identify data collection firm(s)	▲																												
Sampling	▲			▲								i																	
Draft baseline survey questionnaires (quantitative)		▲		▲								m																	
Pilot trip SOW (quantitative)		▲			▲							a																	
Trip to Liberia to oversee pilot (quantitative)			□		□							t																	
Draft interview and focus group protocols (qualitative end users)					▲																								
Trip report, summary of pilot test			▲		▲							e																	
6. Supervise baseline data collection		—	—	—	—	—						d																	
IRB package		▲																											
Trip SOW			▲		▲							C																	
Trip to Liberia for quantitative data collection supervision			□		□																								
Trip to Liberia for high-level stakeholder interviews						□						o																	
Manage and oversee data collection			—	—	—	—						m																	
7. Develop baseline report and data files							—	—				p																	
Draft baseline report (activity 1 & 2)							▲					a																	
Documentation of stakeholder and MCC feedback							▲					c																	
Final raw and analysis files (activity 1&2)								▲																					
Final baseline report (activity 1&2)								▲				t																	
8. Disseminate baseline results								—																					
Baseline report PPT								▲				e																	
Trip SOW								▲				n																	
Trip to Liberia to present baseline results								□				d																	
9. Monitor program implementation	—	—	—	—	—	—	—	—	—	—	—	—																	
10. Revise interim evaluation materials									—	—																			
Data collection firm TORs									▲			d																	
Draft revised survey materials									▲			a																	
Summary of pilot test										▲		t																	
Final revised survey materials										▲																			
Documentation of stakeholder and MCC feedback										▲		e																	

□ Trip to Liberia
▲ Reports/deliverables

Period of performance	Option Period 1						Option Period 2							Option Period 3															
Calendar year	2018			2019				2020				2021				2022				2023				2024				2025	
Quarter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Task																													
11. Supervise interim data collection																													
IRB package										▲																			
Trip SOWs										▲																			
Trip to Liberia to train data collectors (quantitative)										□		E																	
Trip to Liberia for focus groups and interviews with businesses (qualitative)										□																			
Key stakeholder interviews (at least yearly, in person or phone)							▲				□	s																	
Manage and oversee data collection											▲	t																	
12. Develop interim report and data files												i																	
Draft interim report												m	▲																
Local stakeholder feedback with response												a	▲																
MCC feedback with response													▲																
Final interim raw and analysis files												t		▲															
Final interim report												e		▲															
13. Disseminate interim results												d																	
Interim report PPT														▲															
Trip SOW														▲															
Trip to Liberia to present interim results												C		□															
Interim Policy Brief												o			▲														
14. Revise final evaluation materials												m																	
Data collection firm TORs												p							▲										
Draft revised survey materials																			▲										
Summary of pilot test												a								▲									
Final revised survey materials												c								▲									
Documentation of stakeholder and MCC feedback												t										▲							
15. Supervise final data collection																													
IRB package																							▲						
Trip SOWs												e											▲						
Trip to Liberia to train data collectors (quantitative)												n											□						
Trip to Liberia for focus groups and interviews with businesses (qualitative)												d											□						
Key stakeholder interviews (at least yearly, in person or phone)															▲				▲				□						
Manage and oversee data collection												d											▲						
16. Develop final report and data files																													
Draft final report												a													▲				
Local stakeholder feedback with response												t														▲			
MCC feedback with response												e															▲		
Final raw and analysis files																												▲	
Final report																												▲	
17. Review and update Economic Analysis																													
Updated economic analysis and lessons learned for Final Report																											▲		
18. Disseminate final results																													
Final report PPT																												▲	
Trip SOW																												▲	
Trip to Liberia to present final results																												□	

□ Trip to Liberia
▲ Reports/deliverables

X. CHALLENGES TO EVALUATION STUDIES

We recognize and MCC acknowledges the critical risks to the Liberia Energy Project, and in turn to the evaluation components, given that Liberia likely presents higher risks than other countries with Compacts. Liberia is a post-conflict country with political instability, a fragile economic and social environment, fragile institutions and limited technical capacity, and a heavy reliance on donor partners. Liberia lacks a track record of operating and sustaining infrastructure and assets, making the sustainability of Compact outcomes and benefits uncertain. Together, these critical risks present unique and serious challenges to project designs, quality, implementation, and results. These combined risks present evaluation challenges that we address below.

First, we plan to use qualitative performance methods to answer research questions for each level of outcomes. Although do not anticipate serious challenges implementing the qualitative methods, we recognize that we are reliant on Liberian agencies, donor partners, and other stakeholders to supply documentation, maps, and administrative data, participate in interviews, and allow site visits. We are actively establishing relationships with donors and other stakeholders to increase the likelihood that we can consistently obtain the necessary materials and participation throughout the course of the evaluation. Given the long time frame for this evaluation, some implementers, public authorities, and LEC staff may change during the Compact period, complicating our ability to document and assess implementation and results. To mitigate this challenge, we will monitor staff turnover through our contacts at MCA-Liberia, LEC, and other agencies. If feasible, our in-country coordinator will be available on short notice to perform interviews on a rolling basis with exiting staff. Open and regular communication between the evaluation team and in-country stakeholders will be essential to ensuring we reach key informants before their exit.

We also recognize that **implementation and coordination constraints** may arise if large project components are delayed or canceled or if planned technical aspects do not occur in parallel with capacity building investments and regulatory reforms. These constraints may hinder our ability to assess some of the key evaluation questions. To mitigate the effect of these potential constraints on the evaluation, we will document any substantive modifications to implementation plans and incorporate those findings into our analysis. We will also reframe evaluation questions, as necessary, in the case of large-scale modifications or cancellations.

Further, the longitudinal analysis of **administrative data** is dependent upon the availability of adequate data. In meetings with stakeholders during the September 2017 scoping trip and in subsequent conversations, we have discussed the lack of availability and poor quality of administrative data for measuring many key outcomes. LEC currently has no standard system or process to oversee the full system, locate faults, create reports, or monitor its customer base. However, once the MSC has a functional IMS system, more of this administrative data should be available. In addition, system-level SCADA data will help fill the data gap. We would advocate for fast-tracking the substation level SCADA system and investing in data loggers so that high-quality data can be used for monitoring and evaluation. In the absence of a distribution level SCADA system our contingency plan is to use manually captured historical handwritten data. However, data must be assessed to determine whether they are of sufficient quality to use for longitudinal analysis. We recommend pursuing enhanced data collection systems for future efforts.

The stability of the grid expansion plans is critical for our proposed MCG design for unconnected end users because we will identify the intervention and comparison groups based on the planned expansion maps and collect baseline data in these areas. If part of the planned expansions is not realized because of changes in the original plans after our design and baseline data collection, we will not have a full sample for the analysis. We will assess the possibility of this situation happening for the expansion plans underlying our design and will use only mostly finalized and stable catchment areas of expansion segments for the impact study.

The timing of baseline data collection has implications for the MCG design for unconnected end users. Based on the most recent available information, LEC's customer base consisted of 49,000 households as of mid-February 2017 and was scheduled to grow at a rate of 3,900 customers per month.[11] We understand that this growth rate has not been realized and in fact more than half of current customers may not be regularly purchasing electricity. However, as new T&D lines become operational and LEC gains capacity, more customers will be connected in the catchment areas of new T&D lines. This rapid growth may make it more difficult for us to find a reasonably sized sample in the intervention areas to match with households in the comparison areas. It is theoretically possible to include recently connected households in the intervention areas as unconnected (at baseline) end users and match them with unconnected end users in the comparison areas so we will explore this possibility as we gain access to distribution maps. The assumption is that end-user-level outcomes would change very little for recently connected households by the time we would collect baseline information from them.

The sample size for large commercial customers could be an issue for a meaningful longitudinal analysis. According to MCC's economic analysis, there are currently approximately 120 T3 customers and 546 T2 customers; these numbers are expected to rise to 162 and 1,450 customers, respectively, in three years. Currently, LEC is trying to connect large customers. However, as documented in MCC's investment memo, large businesses have minimal trust in the utility company, and they demand reliable electricity with a low tariff. In addition, LEC has very limited capacity to connect new customers. Again, we are exploring the feasibility of including the entire population of large industrial and commercial customers for the longitudinal analysis if the number of these large customers does not increase as expected.

[11] The number of connected users is based on a statement by the LEC managing director, published on LEC's website (http://lecliberia.com/?p=2005). The press release is dated both February 17, 2017, and February 16, 2016. The date of February 2017 is more plausible and is consistent with information on LEC's Facebook page.

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APPENDIX A. EVALUATION DESIGN CHANGES (UPDATED APRIL 2019)

In 2017, the Millennium Challenge Corporation (MCC) contracted Mathematica Policy Research to conduct an evaluation of the Liberia Energy Project. The evaluation scope comprised several studies, including estimating the impacts of electricity on unconnected households and small enterprises. We originally understood that new end users would access grid electricity throughout Greater Monrovia once the Liberia Electricity Corporation (LEC), in partnership with international development organizations, rehabilitated or built new transmission and distribution (T&D) infrastructure, and connected customers. While the design and construction phases of this work has been delayed, our team has learned more about the customer connection approach, including the placement of new poles and lines for these investments. In light of the new information, we must rethink our originally proposed impact study design and suggest an alternative approach. This Appendix describes the rationale for the alternative approach and the key changes to the original design described in the body of this report.

As a point of reference, both the original and the revised design aim to answer the below **research questions (RQ) related to end user outcomes**:

1. To what extent, if any, have the Mt. Coffee Rehabilitation and Capacity Building and Sector Reform Activities affected the number of users connecting to the grid and the demand for electricity?
2. To what extent do customers invest in energy-intensive appliances or equipment? What is the effect of energy on time use? What, if any, are the spillover effects on non-electrified households? How do all of these impacts vary by differences in gender, socioeconomic status, and other demographic characteristics?
3. How did new households, commercial, industrial, and other consumers decide to connect? For potential consumers, why have they not connected? What are barriers to grid connections? How have changes in the reliability of electricity affected connected and unconnected households' perceptions of the quality of electricity? Are there differences in these issues by respondents' gender and socioeconomic status?

Additionally, both the original and the revised design can help answer one of the **overarching implementation research question:**

4. To what extent, if any, does comparing the assumptions made in the forecasted economic model, actual program implementation, and evaluation findings generate lessons that can be applied to future economic models?

Guided by the above research questions, we explain reasons why the original study design described in our Evaluation Design Report (EDR) is infeasible. This memo proposes and describes an alternative pre-post design. We also describe two optional studies to bolster the pre-post design. We end by discussing next steps.

A. Infeasibility of original impact evaluation designs

Mathematica's original plan, described in detail in the EDR for Activity 1 and 2 of the Liberia Energy Project, was to estimate the Energy Project's impact on unconnected households and small enterprises by implementing an impact evaluation using either an instrumental variables strategy, or a difference-in-difference design with a matched comparison group. Both of these designs rely on identifying an intervention and a comparison group in locations where new T&D infrastructure will be constructed from heading out of Monrovia along either the Bomi or Kakata corridors. Identifying two groups of households and small businesses—one which gains access to grid electricity and another in close proximity to the lines but without access to the grid—would have permitted an analysis in which we contrast outcomes between these groups to estimate impacts. However, following ongoing discussions with LEC and the international development partners that are funding the new electricity T&D infrastructure over the course of 2017 and 2018, we understand that the impact evaluation design cannot be implemented for several reasons:

- First, LEC and the donors explained that given longstanding unmet demand for grid electricity, the new T&D infrastructure aims to connect the entire population of households and businesses along the Bomi and Kakata corridors. This construction plan rules out the possibility of finding a suitable comparison group of households and small businesses that will not be connected to the electricity grid. Although we could explore identifying a comparison group formed by unconnected households and small businesses from non-project areas in locations other than Bomi and Kakata, it would require a considerable amount of time for us to identify and analyze existing data (from the census, surveys, and satellite imagery) to identify a comparison group. As many of these data sources are recent and given the relatively few areas to select a comparison group from in Greater Monrovia, we are not confident we could identify a comparison group even with a substantial time investment. Further, given that households and businesses in the targeted intervention areas are likely to be connected in the near future, we think it is necessary to administer a baseline survey as soon as possible. Spending time now on exploration of a comparison group not only bears the risk of missing the time window to administer a true baseline survey in the targeted intervention areas, but also has the possibility that ultimately the comparison areas we identify are not similar enough to the intervention group on key observable characteristics at baseline for the impact evaluation to be valid.
- Second, the initial design is also infeasible as LEC and contractors plan to connect all users in the vicinity in a short period of time. LEC has prioritized maximizing the number of new customer connections they can install rapidly given the growing demand and impatience among Liberians for grid electricity. This means that new connections will not be staggered, ruling out identifying a suitable comparison group among a pool of households and small businesses that will gain connectivity later than the initial household and small business connections and comparing these groups.

As a result of these constraints, we do not believe the originally planned impact evaluation with unconnected households and small businesses is feasible. Instead, we propose the next best alternative which is to conduct a pre-post study of unconnected households and small businesses at multiple time points. We could bolster this approach with two optional studies designed to maximize learning about the process and impacts of electrification: The first optional study aims to demonstrate causal impacts retrospectively using nighttime light data. The second study aims to build on our planned qualitative research by incorporating case studies to obtain deeper insights into end user experiences and decisions around grid connections, evolving perceptions of electricity quality and LEC service provision, and spillover effects. We describe each of these studies below.

B. Pre-post study of unconnected households and small businesses

We propose a pre-post study of unconnected households and small businesses as an alternative to the impact design. This approach is similar to the connected end user study that we are implementing, but unlike the connected study, we will have a clean baseline to understand the economic situation and characteristics of households and small businesses prior to accessing grid electricity. The pre-post design will allow us to collect baseline data and closely observe the unconnected households and small businesses to examine changes at several time points. We continue to propose three rounds of data collection—at baseline in 2019, interim in 2021, and endline in 2023—to form a panel that will enable us to collect information on households and small businesses, and measure changes in a broad range of outcomes such as energy demand and consumption, time use, and economic well-being.

The design enables us to begin to answer RQ1 by bolstering administrative data on connections and customer demand with end user data on consumption and perceptions of whether energy demands are met. We can answer RQ2 by measuring changes in households and businesses energy use, appliance use and purchases, and time use. The proposed design also allows us to answer RQ3 on how households and small businesses decide to connect, changes in perceptions of electricity quality, and differences by user type. However, for each of the questions, without a comparison group, we cannot directly attribute changes to the electricity project. Nevertheless, we can assess the degree to which many of the changes are influenced by electricity connections, some of which are self-evident. We will use our knowledge of the timing of grid infrastructure construction, as well as other factors that might influence outcomes, to assess the likelihood that changes are due to the project. Further, while this design does not allow us to examine spillover effects directly with non-electrified households quantitatively, we can ask households, businesses, and other stakeholders about their perceptions of possible spillovers during the planned qualitative focus group discussions and interviews.

Finally, for RQ4 related to the economic return on the project, we had anticipated that we would use data and findings from each of the evaluation studies to assess the underlying assumptions and update the parameters in the benefit-cost analysis and economic rates of return model. Because we no longer have an impact evaluation, for the economic rates return model, we will not have a rigorous estimate of the benefits as would have been captured by the estimated impacts of electrification on household and business outcomes. Nevertheless, we can still address RQ4 with the pre-post design with few unavoidable modifications. The change in design means that we rely on administrative data and survey questions in the connected and unconnected pre-post study to measure demand for new connections. We will also rely on these surveys for data on the demand for already connected consumers and consumer willingness to pay. The model also requires data on tariffs, generation costs, technical losses, costs of household connections, and beneficiary population data will not be affected by the change in design.

1. Study area and data collection timing for the pre-post study

Next, we describe the lowest risk sampling option for the pre-post study and identify its advantages and disadvantages. We suggest conducting the study along the Kakata corridor where the World Bank is funding construction of T&D infrastructure with the goal of connecting 17,000 new users. An advantage of focusing on this sample, rather than other corridors with planned infrastructure investments, is that we have the construction plans for the Kakata corridor in hand and can proceed with planned data collection starting in April 2019. This is the simplest approach with the lowest level of risk given that with construction underway, we are confident the connections will be made and our study sample will be complete. Note that we do not recommend delaying data collection beyond second quarter of 2019 as we would risk missing a clean baseline as households and small businesses are connected and begin consuming electricity. A disadvantage is that this smaller study area may not be generalizable to the rest of Liberia if households and businesses along the Kakata Corridor are uniquely different to other areas of the country. However, generalizability would have been a challenge even if we were able to carry out the planned impact evaluation for the Kakata corridor; so this is not unique to the pre-post study design.

We had considered expanding data collection to cover communities that will be funded by other donors such as African Development Bank (AfDB), the German Development Bank (KfW), and the European Investment Bank (EIB). AfDB aims to connect 25,000 end users along the Roberts International Airport (RIA) Corridor, KfW aims to connect 17,500 end users and the EIB aims to connect 38,000 end users across Greater Monrovia. In addition, the World Bank (WB) aims to connect another 20,000 end users along the Bomi Corridor. The advantage of collecting data from a broader array of communities is that results from the pre-post study can be generalized to a more diverse group of end users that are located across Greater Monrovia and beyond, rather than respondents who are concentrated along one corridor. However, a critical disadvantage is that the T&D infrastructure design plans for the projects funded by AfDB, the EIB, and KfW are not yet available and there is no definitive date for when they will be prepared. Also, the WB funded project along the Bomi Corridor is delayed because of issues surrounding resident resettlement. Without design plans, we cannot confidently identify the project target areas and select a sample of households and small businesses that will definitely be located in areas with access to electricity and commence data collection in January 2019 or shortly thereafter. We want to acknowledge that each donors' design plans had been scheduled to be completed in 2018, with new construction, and connections planned for 2019; however, given repeated and excessive delays to date, we are concerned that postponing the study until all design plans are available is risky because some of the investments may not come to fruition.

At this time, we recommend conducting the pre-post study in the Kakata Corridor. We also recommend bolstering this study with the proposed optional studies described in this memo.

2. Sample size

We revised our sample size calculations from the previous impact study to reflect the pre-post design and the fact that we will no longer compare outcomes between an intervention and comparison group, and will instead compare outcomes within the intervention sample over time. Similar to the EDR, we compute the minimum detectable impacts (MDIs) for monthly energy consumption from any source. Table 1 presents the MDIs for different cluster sample sizes (number of enumeration areas), provided that we will be sampling 10 units per cluster on average as originally planned. We believe that a reasonable division of the 10 units per cluster is to interview 7 households and 3 small businesses per cluster, on average, because we expect relatively fewer businesses per cluster from our experience of conducting the baseline survey for the connected study. The calculations on Table 1 reflect this division between households and small businesses for sampling.

Table 1. Minimum detectable impacts for unconnected households and small businesses: Pre-post study design

Outcome	Sample size		Baseline mean	MDI	MDI (% change from mean)
	Clusters	Households/small businesses			
Sample of households					
Monthly grid electricity consumption (kWh)	150	1,050	6.92	4.6	66.8
	125	875	6.92	5.1	73.2
	100	700	6.92	5.7	81.9
Sample of small businesses					
Monthly grid electricity consumption (kWh)	150	450	6.92	6.0	87.2
	125	375	6.92	6.6	95.5
	100	300	6.92	7.4	10.6.8

Notes: Calculations are based on a confidence level of 95 percent, two-tailed tests, 80 percent power, 10 percent non-response rate for surveys, a pre-post correlation of 10 percent and an R-squared of 0.3 for individual level covariates and .1 for cluster level covariates. We assume a cluster ICC of 0.1, and a coefficient of variation of 5. Information on baseline mean is from World Bank WTP survey of unconnected households in Monrovia. kWh= Kilowatt-hour.

We determined that a sample size of 125 clusters with 7 households and 3 small businesses per cluster would allow us to detect small changes in average monthly electricity consumption in the order of 5.1 kWh for households and 6.6 kWh for small businesses. This sample size is approximately half of what we required to detect impacts of a similar magnitude (6.37 kWh) in the original study design (Miller et al. 2018).[12]

3. Timeline, key outcomes, and analytic framework

Once again, we propose to keep the timeline for data collection and key outcomes the same as in the original study design. In particular, we plan for baseline data collection in April 2019 and follow-up data collection in January 2021 and January 2023. We will measure outcomes related to connection rates, energy use, education and child time use, health and safety, business and adult time use, and economic well-being (as in Table VI.6 in Miller et al. 2018).

[12] In the original study design, we only presented MDIs for the sample of households and small businesses combined, not distinguishing between whether MDIs are for the sample of households or small businesses. To be more precise, we present the MDIs for households and small businesses separately in this memo because we would like to detect changes in outcomes for both entities.

Following our pre-post study of connected end users, we will use the following linear ordinary least squares model to changes over time in outcomes of unconnected households and small businesses:

$$Y_{ec} = \alpha + \beta_1' Post + \beta_1' X_{ec} + \mu_e + \varepsilon_{ec}$$

where Y_{ec} is the outcome of interest of household/business *e* (pre or post) in cluster *c*; post is an indicator variable that is one if the outcome is from the post-implementation period (either the first follow up or second follow up) and zero otherwise; X_{ec} is a vector of the time-variant background characteristics of household/business *e* and community *c*; μ_e represent household/business-level fixed effects; and ε_{ec} is an error term. The coefficient β_1 represents the adjusted change over time in the end-user outcome.

C. Optional exploratory analysis using satellite imagery

A pre-post study will not allow us to rigorously estimate causal impacts of the Liberia Energy Project because other unobserved factors separate from the project might account for some of the changes in observed outcomes during the study period. However, data from our pre-post study paired with readily available nighttime lights (NTL) data collected from satellites might allow us to retrospectively identify the causal impacts of the project at little additional cost. This exploratory impact analysis can be performed toward the tail end of the evaluation, after follow-up data collection is complete. We envision two types of analysis:

- First, given that recent literature has shown that the amount or intensity of NTL is correlated with electrification (Elvidge et al. 2011; Machemedze et al. 2017) we propose an analysis in which we correlate changes in night lights to changes in economic outcomes (like connection rates, income, and economic activity) that are found in the pre-post study. This enables us to quantify the economic significance of changes in night light intensity.
- Second, we propose to conduct a retrospective quasi-experimental study to estimate the causal impact of the project on night time light intensity. Using data on NTL prior to the intervention date, we might be able to identify comparison areas where no project lines were built but are otherwise similar to the intervention areas where project lines were built. We can use satellite imagery and other secondary data to assess pre-intervention equivalency of the intervention and comparison areas. We can then compare changes in NTL between these areas. We will interpret the economic significance of changes in NTL based on our correlational findings between economic outcomes and NTL in the pre-post study. This will allow us to quantify the changes in economic outcomes of the households and businesses that are plausibly attributable to the project.

The advantage of using NTL data is that we can conduct a finely grained study that compares changes that occur in the precise geographic location of where new lines were built versus comparison areas. It would also allow us to demonstrate how NTL data and satellite imagery could be useful for other MCC investments in the future. The NTL analysis however cannot be conducted unless we map out the exact geographic location of project poles when we conduct the pre-post study. We are planning to collect this information in project locations and will geographically map the electricity poles if this optional analysis is of interest to MCC.

D. Optional journey mapping with qualitative case studies

Next we propose qualitative case studies that closely examine customers' journeys and experiences as they gain access to electricity by conducting annual interviews with a select sample of households and small businesses. These qualitative case studies will bolster the qualitative research we already planned to carry out. Specifically, in our original design for the unconnected study, we planned to conduct qualitative focus group discussions with households and interviews with small business owners at three time points, in 2019, 2021, and 2023. The timing of these activities aligns with the quantitative surveys. Even though we are changing to a pre-post study, we still plan to conduct these focus groups and interviews to investigate connection decisions and energy-related behaviors at three discrete points in time.

The added value of additional qualitative case studies would be to allow us to capture the dynamic changes and nuances in household and small businesses' behavior and choices more frequently as well as explore the experiences of respondents from more project areas. We would obtain deeper insights into the unfolding processes that occur as grid electricity becomes available, including the evolving decisions around grid connections, electricity use and experiences, and LEC service provision. During one hour face-to-face interviews, we would also assess spillover effects of electrification from the perspective of connected households. These case studies would provide greater insight into RQ1, RQ2, and RQ3 and complement the pre-post analysis by providing richer insights into priority outcomes across seasons and time. The additional data would also help to more confidently determine whether changes are related to electrification, improvements to LEC's infrastructure and operations, and energy sector reforms. Findings from this study will provide a unique window into the user's experience and journey, helping to explain their energy use and behaviors, so that future planning and expectations will be informed by actual usage patterns and user's experiences. This is important given the persistent and documented concerns with LEC's service provision and that improvements to the energy sector's functionality and to LEC's overall operations are central to the theory of change.

1. Sampling frame and size

We envision selecting a sample of approximately 20 to 40 respondents for these interviews from multiple locations (see Table 2 for the sampling plan for the qualitative case studies). We would aim to maximize the breadth of respondents, including both households and small businesses, to optimize this study's learning potential given the dearth of data and literature on electrification processes, decisions, and outcomes in the Liberian context. We propose to select a sample of respondents from the donor funded project activities, funded by AfDB, the EIB, KfW, and the World Bank as these projects come to fruition creating new electricity connections along the Bomi, Kakata, and RIA Corridors and additional communities within Greater Monrovia.

Table 2. Sampling plan for qualitative case studies

	2019	2020	2021	2022	2023
Sample selected from these locations	• Kakata Corridor (outside of quantitative survey areas)[a]	• Kakata Corridor • RIA Corridor[a]	• Kakata Corridor • RIA Corridor • Bomi Corridor • Monrovia Consolidation project recipients	• Kakata Corridor • RIA Corridor • Bomi Corridor • Monrovia Consolidation project recipients	• Kakata Corridor • RIA Corridor • Bomi Corridor • Monrovia Consolidation project recipients
Connected households	20	20	20	20	20
Connected small businesses	[b]	20	20	20	20

Notes: [a] Other project areas if customer connections planned pending.

[b] In-depth qualitative interviews with small businesses in the Kakata corridor already planned under the existing evaluation design

We will select the sample for the in-depth interviews using a purposive sampling approach targeting the new project areas once AfDB, EIB, KfW, and additional WB funded infrastructure is functional. Acknowledging that there may be continued delays in the construction of new lines that stretch beyond 2019, we propose beginning by conducting the case studies along the Kakata corridor because we can be confident that the electricity connections will be made. Over time, we will replace some of the Kakata corridor respondents with end users along the additional corridors, and add interviews with small businesses in the other corridors (see Table 2). In other words, we aim to follow some of the same respondents over time to understand any changes in decision making and energy behaviors, and will also replace some respondents with new users depending on how the electrical connections unfold and based on what we learn during quantitative and qualitative data collection and our project monitoring activities. Using a somewhat organic approach, determined by interesting questions that arise over the course of the study, enables us to maximize learning and understanding of the behavior changes and actions of households and businesses related to electricity demand, usage, and related outcomes.

We will select respondents across the following donor-funded projects.

- We will conduct focus groups with connected households and interviews with small businesses along the Paynesville-Kakata Corridor in the existing qualitative study, and add respondents to this sample for the case study interviews.
- Once the additional projects come online, we will aim to follow end users living in the following catchment areas post-compact:
    - End users along the Roberts International Airport (RIA) Corridor (AfDB aims to make 25,000 connections)
    - End users along the Bomi Corridor from St Paul Bridge to Tubmanburg (the World Bank aims to make 20,000 to 30,000 connections)
    - End users in the EIB sponsored Monrovia Consolidation Project and the KfW project, which aim to connect an estimated 38,000 and 17,500 customers respectively.

Note that we plan to revisit this proposed qualitative sampling plan after analyzing the baseline data, and may make revisions as necessary.

E. Next steps

We worked closely with MCC to determine the preferred unconnected study design that answers the priority research questions. As a next step, we look forward to discussing the optional study designs (exploratory analysis using satellite imagery and journey mapping) with the MCC and MCA teams.

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APPENDIX B. DATA COLLECTION CHANGES (UPDATED OCTOBER 2020)

By June 2020, the Millennium Challenge Corporation (MCC) had paused data collection activities for the year due to the Covid-19 pandemic. As of July 2020, MCC began requiring that independent evaluators conduct a risk assessment and propose mitigation strategies to reduce the chance of COVID-19 exposure and transmission during in-country evaluation activities. We have reflected on the implications for the Liberia energy evaluation, assessed the approaches to our planned interim data collection, and considered the adaptations necessary to proceed with the study. This Appendix describes our approach for telephone-based survey data collection for the Liberia energy evaluation during the global COVID-19 pandemic. Note that we only describe here changes to the interim round of data collection for the connected study in Monrovia, which was scheduled for November to December 2020. This includes survey data collection with community leaders and the household and small business respondents. For now, we do not include recommendations for changing the interim round of data collection for the unconnected study along the Kakata Corridor or the medium and large end user study, which are set to occur in 2021.

A. Background

The Government of Liberia declared a state of emergency in April 2020 at the onset of the Covid-19 pandemic. As of October 28, 2020, the state of emergency had been lifed and Covid-19 transmission remained relatively low with 1,419 confirmed cases and 82 deaths out of a population of 4.8 million. The country's experience with the Ebola Virus Disease may havae informed the Covid-19 response. Still, Liberians are encouraged to continue to take precautions. The economy is slowly returning to the pre-Covid state. Despite the spread of the virus being relatively contained, many in the country still lack access to testing, the health system is poor, and outbreaks could occur at any point, as demonstrated by the experience of other countries. As of September 2020, according to the Center for Disease Control and Prevention the risk of contracting COVID-19 in Liberia is high, though the number of reported new cases per day has been modest at under 50 cases per day countrywide. *(The following webpage provides regular updates and trends: https://covid19.who.int/region/afro/country/lr)*

The interim data collection activities, as described in more detail in this report, were designed to contribute to answering MCC's priority evaluation questions about implementation and outcomes and to maximize utility for MCC and Liberian stakeholders. Continuing this data collection round is thus preferred to waiting several years for endline data collection and reporting to evaluate impacts. Additionally, the interim data collection round presents an opportunity to document the short-term effects of COVID-19 on households and businesses, which may ultimately influence energy related outcomes that are of primary interest to the energy evaluation.

B. Telephone and supplemental in-person surveys

Mathematica's original plan was to collect data for the connected study in the interim round through in-person surveys with communities, households, and small businesses in November and December 2020. In light of the pandemic and following MCC's requirements, we now propose to collect these data primarily through phone surveys following the original timeline and to supplement these with in-person surveys only if response rates for the surveys are too low (below 80 percent). We considered the following pros and cons to this approach:

Pros	Cons
• Shifting to phone surveys eliminates the risk of COVID-19 transmission; limited in-person surveys while following COVID-19 guidelines would also minimize transmission risks • Following the original timeline with the phone surveys (and not postponing in-person data collection to when COVID-19 no longer presents health risks), allows us to collect timely data and mitigates seasonality issues with our pre-post evaluation design because the data are collected at the same time of the year at baseline, interim, and endline • Our data collection local partner, The Khana Group (TKG), has previous experience with phone surveys. TKG has followed best practices for remote surveys as recommended by the World Bank. In two of their recent remote surveys, they achieved response rates of 77 and 75 percent out of a sample of 518 and 1245 individuals. The surveys took around 50 minutes. • We have the phone numbers for 92% of the household and small business samples from our baseline data collection. For more than half of these samples, we have multiple phone numbers. We suggest calling a small sample of these respondents prior to data collection to assess the quality of the phone numbers. • Mathematica has recently deployed phone surveys for data collection in Burkina Faso and Benin and we have learned from best practices during these experiences.	• The phone surveys will have to be shorter than what the in-person survey should have been so that respondents remain engaged during the telephone interview. Therefore, we will have to reduce the number of questions in the survey. • Phone surveys may have lower response rates than in-person surveys; Mathematica's phone survey in Burkina Faso had a 78 percent response rate when compensation was not provided • For safety reasons, Mathematica will be unable to oversee data collection in-person in Liberia. Training will be done remotely. However, both Mathematica and TKG have conducted remote training and have established best practices in remote training for data collection.

For the phone surveys, training and coordination will be done fully online and enumerators will complete interviews with respondents through phone calls from their own residences. The subcontractor will drop off the equipment necessary to conduct these phone surveys at the enumerators' homes. This would eliminate the risk of COVID-19 transmission between staff and respondents. To increase response rates, the plan is to compensate respondents with telephone airtime worth 2 USD. Our data collector in Liberia has experience with compensation provision. In one of their recent remote surveys, they offered a $1 phone credit to respondents. They worked out a system with one of the local cell phone companies to remotely transfer the compensation to respondents within 24 hours.

For the supplemental in-person surveys, if these are necessary, we will comply with all local regulations and will carry out MCC-recommended risk-mitigation procedures and additional measures needed to comply with the World Health Organization guidelines for a "medium risk" work environment. These measures include the following steps:

- All data collection staff will be screened each morning for symptoms using a temperature check and by completing a COVID-19 symptom questionnaire provided by MCC. Any team-member showing symptoms will return home immediately and will not be allowed to survey a household or business or interact with respondents in any way. TKG will follow all Liberian government requirements regarding reporting illness (specifically, using the government's reporting phone number for positive cases, and requiring any staff-member with known contact with a positive coronavirus case or a temperature above 100.4 degrees to self-isolate for 2 weeks).

- The subcontractors will provide all data collection staff visiting households and businesses with cloth masks and rubber gloves. Masks and gloves will be worn by data collection staff at all times during visits. Disposable masks will be provided to respondents to be worn during interviews.

- Data collection staff will travel to their field site with necessary materials for sanitation: (1) liquid hand sanitizer for use throughout the visit; and (2) disinfecting wipes for computer tablets and any other physical materials that will be shared by more than one person.

- All data collection will be carried out in accordance with the WHO and Liberian government recommendation to enforce physical distancing of at least 1 meter between individuals. All interviews will be conducted outdoors with no table in well-lit but relatively isolated areas to protect confidentiality of survey responses.

- Subcontractors will follow Liberian government requirements for safe transportation to work. All transportation will occur using private cars, and private car use will be limited to 1 driver and 3 passengers. Masks will be worn by data collection staff at all times during transportation.