REPORT

FINAL REPORT

Evaluation Design Report for the Benin Power Compact's Electricity Generation Project and Electricity Distribution Project

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ACRONYMS

AMI	Advanced Meter Infrastructure
AMR	Automatic Meter Reading
BTI	Business and Technology International
CAPI	Computer-Assisted Personal Interviewing
CEB	Communauté Electrique du Benin
ERR	Economic Rate of Return
FGD	Focus Group Discussions
GDP	Gross Domestic Product
GoB	Government of Benin
GPS	Geospatial Positioning System
GSI	Gender and Social Inclusion
GW	Gigawatts
HV	High Voltage
IEA	International Energy Agency
IEG (World Bank)	Independent Evaluation Group
IFC	International Finance Corporation
IGA	Income-Generating Activity
INSAE	Institut Nationale de la Statistique et de l'Analyse Economique
IPP	Independent Power Producer
IRB	Institutional Review Board
ITS	Interrupted Time-Series
ITT	Intent-to-Treat
kV	Kilo Volt
kWh	Kilowatt-Hour
M&E	Monitoring and Evaluation
MCA-Benin	Millennium Challenge Account-Benin II
MCC	Millennium Challenge Corporation
MDI	Minimum Detectable Impact
MV	Medium Voltage
MW	Megawatt
MWh	Megawatt Hour
NA	Not Applicable
NDCC	National Dispatch Control Center
PV	Photovoltaic
RCT	Randomized Controlled Trial
RD	Regression Discontinuity
RFP	Request for Proposals
RQ	Research Question
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SBEE	Société Béninoise d’Energie Electrique
SCADA	Supervisory Control and Data Acquisition
TOT	Treatment on the Treated
UN	United Nations

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I. INTRODUCTION

Similar to many countries across sub-Saharan Africa, Benin is severely lacking in electrical power, with critical deficiencies in energy access, installed capacity, and overall consumption. Benin ranks among the lowest in total net electricity generation globally (at 192 out of 198 countries) and depends heavily on imported fuel and electricity, importing 85 percent of its petroleum products from Nigeria and the vast majority of its electricity from Nigeria, Ghana, and Cote d’Ivoire (World Bank 2016). The country also relies heavily on nonrenewable sources of energy, such as firewood, charcoal, and petroleum products. Electricity access is low and uneven: Benin has a household electrification rate of only 28.2 percent nationally and 4.5 percent in rural areas (Climate Investment Funds 2015; International Energy Agency 2015; U.S. Energy Information Administration 2014). Due to its reliance on imports and inability to develop adequate electricity infrastructure, Benin has until recently suffered from a widespread scarcity of electricity. This situation changed with the government’s large-scale installation of rental electricity generation capacity in the form of diesel-powered generators, but at a substantially higher cost.

Benin’s electricity supply challenges stemming from both frail electricity infrastructure and the weak financial condition of the electric utility pose a significant barrier to economic progress. Due to political pressures to keep electricity retail prices low, the cost of supplying electricity has consistently exceeded the tariff paid by consumers. The low quality of the supply of electricity in Benin, characterized by voltage fluctuations and outages, also limits usage and further reduces revenue for Benin’s electricity distribution company, Société Béninoise d’Energie Electrique (SBEE) (Louw et al. 2008). This situation has led to a history of deficits and restricted maintenance for SBEE, which in turn resulted in further deterioration of electricity infrastructure and equipment, an inability to prevent electricity shortages, and inadequate resources to expand the grid. Although SBEE’s financial situation has improved modestly in recent years, both the costs of service and deficit have been increasing (The World Bank 2017c). Overall, this poor electricity infrastructure hinders economic growth in Benin, as businesses, public institutions, and households are constrained by power outages and lack of access to the grid.

To address some of these challenges, the Millennium Challenge Corporation (MCC) has partnered with the Government of Benin (GoB) to implement the Benin Power Compact (also known as the Benin II Energy Compact) from 2017 to 2022. The compact aims to modernize Benin’s electricity network, strengthen SBEE, extend access to electricity, and improve the quality and reliability of the electricity system. MCC has contracted with Mathematica Policy Research (Mathematica) to conduct an evaluation of two of the four compact activities: (1) the Electricity Generation Project, which aims to increase domestic generation capacity through new solar plants and possibly a thermal power plant, and the rehabilitation of an existing hydroelectric plant; and (2) the Electricity Distribution Project. The latter aims to strengthen the grid through upgrades; repairs; installing new switchgears, lines, and connections; and constructing a new national electricity distribution control center, as well as connecting 10,000 new households to the grid in Cotonou, Benin’s largest city, and possibly other project areas.[1]

[1] The other two compact projects are the Policy Reform and Institutional Strengthening Project, which aims to improve the governance and management of the electricity sector, and the Off-Grid Electricity Access Project, which will finance off-grid renewable energy systems.

The evaluation of these two projects involves a comprehensive mixed-methods approach, which will seek to measure the impacts of and understand the changes related to the Electricity Generation and Distribution Projects. Where relevant, we will disaggregate the evaluation by key demographic dimensions to understand the programs' effects on gender and social inclusion (GSI). We will use quantitative data to address several research questions through impact analyses (using an interrupted time-series approach and conducting an optional randomized control trial) and a performance evaluation (using a pre-post analysis). We also will conduct a qualitative performance evaluation to answer the remaining research questions related to implementation and outcomes.

Quantitative impact and performance evaluation. We will use an **interrupted time-series (ITS) design** to estimate impacts on grid and end-user outcomes. The ITS of grid-level outcomes will leverage high-frequency data from data-logging monitors and smart meters installed on the electricity network, combined with information about project rollout, to evaluate changes in key measures of electricity reliability and quality. The continuous collection of grid-monitoring data and data from smart meters will allow us to assess impacts on grid-level outcomes, such as voltage stability and power outages. In addition, Mathematica will use the information on grid-level outcomes in combination with high-frequency phone survey data to conduct an ITS analysis of the impact of compact improvements on the short-term outcomes of households and small, medium, and large businesses. These methods will provide rigorous evidence of the impact of generation and distribution improvements on grid-level and end-user outcomes. Mathematica also proposes an optional impact evaluation to leverage the grid expansion in Cotonou and other project areas to study strategies encouraging urban households to connect to the grid. In the proposed approaches, we would use a **randomized control trial** or a **regression discontinuity design** to rigorously estimate the impacts of different pricing strategies on connecting urban households to the grid and the subsequent impact of connecting on other outcomes. To understand medium- and longer-term outcomes, we will complement the impact analyses with a quantitative performance evaluation (a **pre-post analysis**) of how grid-level, household, and business outcomes change over time.

Qualitative performance evaluation. Mathematica will also answer research questions related to project implementation and sustainability using (1) an implementation analysis, which will explore the compact's processes and activities through document review and interviews; and (2) a qualitative assessment, which will use interviews and focus group discussions to understand long-term outcomes for households, businesses, and public institutions. These evaluations will provide additional information to contextualize and interpret the quantitative findings, and help answer research questions that do not lend themselves to impact evaluations.

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 Electricity Generation and Distribution Projects, and the economic rate of return (ERR). In Chapter III, we review the existing literature on improving electricity supply, quality, and reliability, and the impact on households and businesses. In Chapter IV, 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. Next, we describe the quantitative evaluation designs for estimating the impacts of electricity improvements on grid outcomes (Chapter V) and end-user outcomes (Chapter VI). In Chapter VII, we describe design and data sources for the qualitative performance evaluation. We conclude in Chapter VIII with a discussion of several evaluation administration-related issues, including institutional review board (IRB) requirements, the data anonymization process, our dissemination plan, and evaluation team roles and responsibilities. In Appendix A, we describe the optional impact evaluation to estimate impacts of different pricing schemes.

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II. OVERVIEW OF THE COMPACT, GENERATION ACTIVITY, AND DISTRIBUTION ACTIVITY

In this chapter, we provide context for the evaluation of the Electricity Generation and Distribution Projects by describing project activities and the mechanisms through which they are expected to affect outcomes, as set out in the program logic. We describe the ex-ante ERR that MCC calculated to compare the expected benefits and costs of the project, as well as the beneficiary analysis, which estimated the expected distribution of income gains in the areas where the investments will be made.

A. Overview of the Benin Power Compact

On September 19, 2015, MCC and the GoB signed a $375 million compact agreement to improve Benin's electricity network, the financial position of the national utility, and the quality and reliability of the electricity system, while also expanding access to electricity. The compact, which entered into force on June 22, 2017,[2] comprises four projects: (1) the Electricity Generation Project, which will increase Benin's domestic generation capacity through the construction of new solar power plants (or support to independent power producers [IPPs] to produce power plants[3]) and rehabilitation of a hydropower plant (and possibly the construction of a thermal power plant); (2) the Electricity Distribution Project, which will rehabilitate Benin's declining distribution infrastructure and build a national electricity distribution control center in Cotonou; (3) the Policy Reform and Institutional Strengthening Project, which will support the regulatory authority, encourage private investment, and work to establish a cost-reflective tariff, among other activities; and (4) the Off-Grid Electricity Access Project, which will support policy reforms and infrastructure financing for off-grid projects. Mathematica is designing and conducting an evaluation of the Electricity Generation and Distribution Projects.

The **Electricity Generation Project** will increase Benin's domestic generation through three activities: (1) the construction of four solar photovoltaic (PV) power plants in the cities of Bohicon, Djougou, Natitingou, and Parakou; (2) the rehabilitation and increase in capacity of the Yeripao hydropower plant, located near Natitingou; and (3) the possible construction of a thermal power plant at Parakou (see Table II.1). Specifically, the solar power activity will provide 45 megawatts (MW) of new power generation capacity through the construction of two 15-MW solar PV plants, one 10-MW PV plant, and one 5-MW PV plant in the northern part of the country, where solar irradiance is the highest. The sites are all located near substations that feed the high-voltage (HV) network, so the new electricity generated can be injected into the national grid. However, the primary beneficiaries of this increased capacity are expected to be households and businesses in the project areas, because the new electricity production will first be used to eliminate daytime load shedding in project areas. As part of the project preparation, Millennium Challenge Account-Benin II (MCA-B) will acquire the sites, apply for the necessary permits, and prepare the environmental and social impact assessment. Depending on the

[2] Because the entry into force was delayed, the timelines presented in this report are subject to change.

[3] MCC is considering the option to have IPPs construct the solar power plants. At the time of writing, MCC had launched a request for proposals (RFP) for a consultant to develop the IPP framework and to serve as transaction advisor for an RFP for the solar power plant construction. Mathematica does not anticipate that the involvement of IPPs would affect the evaluation design or implementation.

proposed mitigation strategies, MCA-B, its contractors, or the IPP(s) will address environmental and social risks.

Table II.1. Benin Energy Compact: Activities and investments

Project	Activity	Location	Investment purpose
Electricity Generation Project	PV generation	Parakou	New 15-MW PV plant or support to IPP for construction of PV plant
	PV generation	Natitingou	New 5-MW PV plant or support to IPP for construction of PV plant
	PV generation	Djougou	New 10-MW PV plant or support to IPP for construction of PV plant
	PV generation	Bohicon	New 15-MW PV plant or support to IPP for construction of PV plant
	Hydroelectric generation	Yeripao (near Natitingou)	Rehabilitation of hydropower plant
	(Thermal generation)	Parakou (proposed location)	New 25-MW thermal plant (under consideration)
Electricity Distribution Project	Regional grid strengthening	Natitingou	Natitingou network modifications: modify existing Natitingou substation, construct new northern distribution substation
	Regional grid strengthening	Parakou	Parakou network modifications: modify Parakou substation
	Regional grid strengthening	Djougou	Djougou network modifications: modify Djougou substation
	Regional grid strengthening	Porto Novo to Akpakpa	Porto Novo network modifications: construct new 63-kilovolt (kV) connection to Akpakpa substation (Cotonou), upgrade substations along the line,
	Regional grid strengthening	Across all project areas	General network projects: install compensation equipment and sectionalizing switches
	Cotonou grid strengthening (capacity increase subactivity)	Cotonou	Upgrade Vedoko substation, create new 63-kV connection from Vedoko to Akpakpa and a new 63-kV cable ring leaving Vedoko; construct new step-down distribution substations; expand network in Cotonou, including 10,000 new customer connections (connections may be in other project areas)
	Cotonou grid strengthening (reliability subactivity)	Cotonou	Create transmission grid connection at Maria Gleta, upgrade 15-kV substations and infeed connections to 63 kV, modify switchgear, reconfigure distribution substations
	National electricity dispatch	National	Build new national distribution control center
	National electricity dispatch	National	Begin preparation work for distribution substations and installation of automatic meter reading (AMR) and advanced metering infrastructure (AMI) meters for large industrial customers

The Electricity Generation Project also includes the rehabilitation of the Yeripao hydropower plant. Specifically, MCC will fund project preparation, rehabilitation of the existing generation unit, installation of an additional turbine that will provide an additional 0.5 kW of electricity, rehabilitation and possible expansion of the access road, and removal of sedimentation from the reservoir if necessary (MCC 2015). After these activities, the Yeripao hydropower plant is expected to have 1 MW in generation capacity.

MCC had originally planned to rehabilitate several thermal power plants with a capacity of approximately 32 MW (Ksoll et al. 2017). However, the government is now rehabilitating those plants on its own, so MCC is working on a proposal to build a thermal generation unit with 25 MW of capacity in Parakou, as shown in Table II.1, though this activity is currently unsure.

The **Electricity Distribution Project** comprises four activities (see Table II.1 for an overview and Table B.1 in Appendix B for a detailed list of activities):

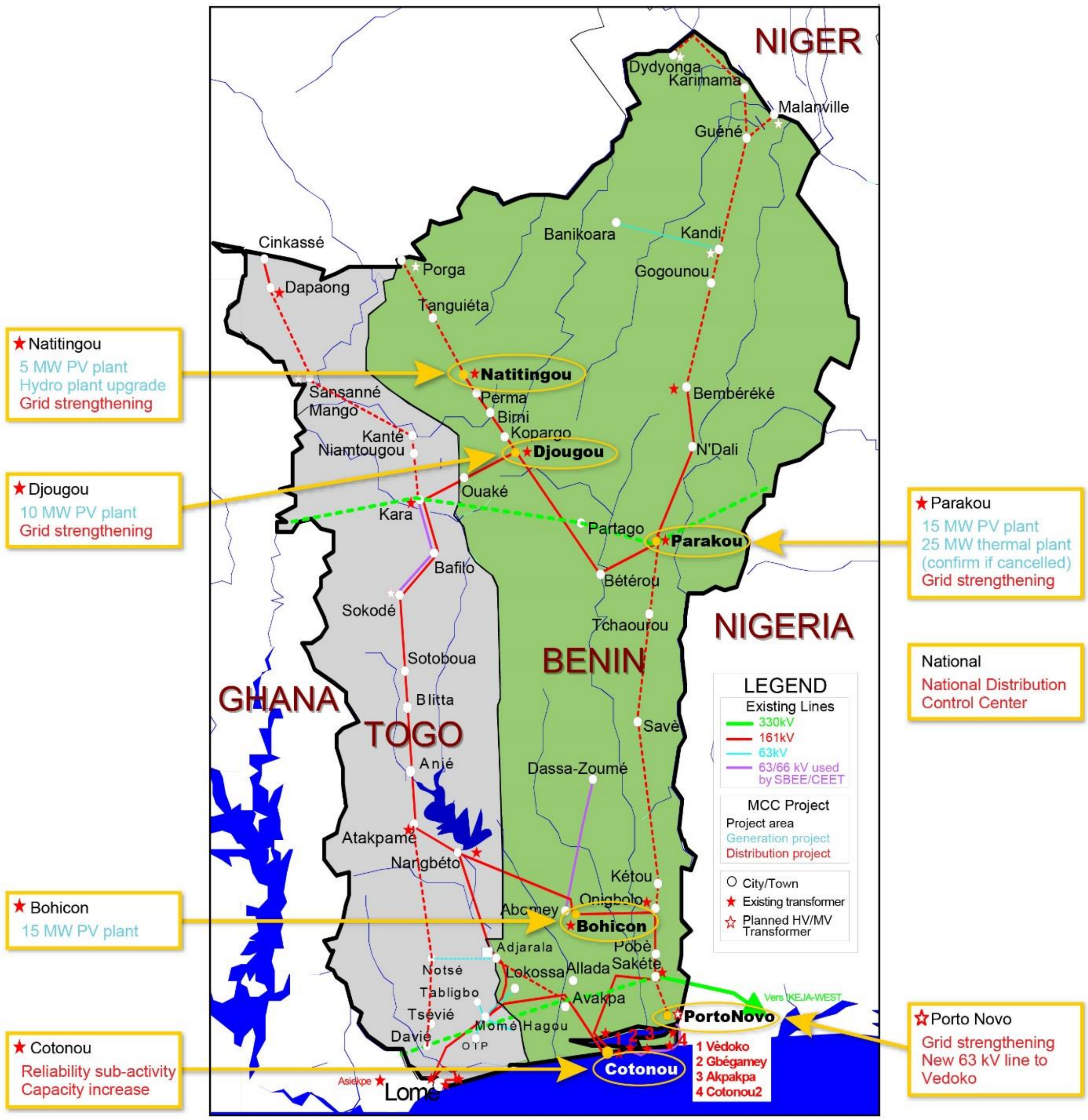
- For the **Regional Grid Strengthening Activity** in Djougou, Natitingou, Parakou, and Porto Novo, MCC will replace electricity lines, upgrade substations, install new switchgear connections, build new substations, and construct a new 63-kV connection from Porto Novo to Akpakpa[4]. These activities will be concentrated in the same areas receiving new solar PV plants and will improve the grid's ability to handle increased demand while also reducing technical losses.
- The **Cotonou Grid Strengthening Activity** aims to improve the capacity and reliability of the grid in Benin's largest city through installation of new switchgears, connections, and busbar feeders, network extensions, and switchgear modifications.
- The **National Electricity Dispatch Activity** will improve SBEE's ability to manage the national grid and respond to problems through the construction of a national distribution control center (NDCC). The NDCC will include supervisory control and data acquisition (SCADA) equipment.[5]
- General network modifications in the project areas.

Overall, these investments aim to increase the capacity of Benin's electricity grid in the project areas, improve the reliability of electricity supply to consumers, and help SBEE identify problems early on and respond to them more quickly. A map of the project regions and planned activities is presented in Figure II.1.

[4] The Regional Grid Strengthening Activity, as described in the compact, originally included plans to upgrade rural lines and provide direct MV connections to the 10 biggest industrial customers in Parakou; however, as of the writing of this report, these activities had been eliminated from the budget.

[5] The original compact included a plan for MCC to invest in the installation of automatic meter reading (AMR) and advanced metering infrastructure (AMI) for large industrial customers. These meters allow for the instantaneous transmission of information on electricity usage to the NDCC and could enable it to remotely disconnect customers to manage loads on the network. This component is currently contingent on funding.

Figure II.1. Map of project regions



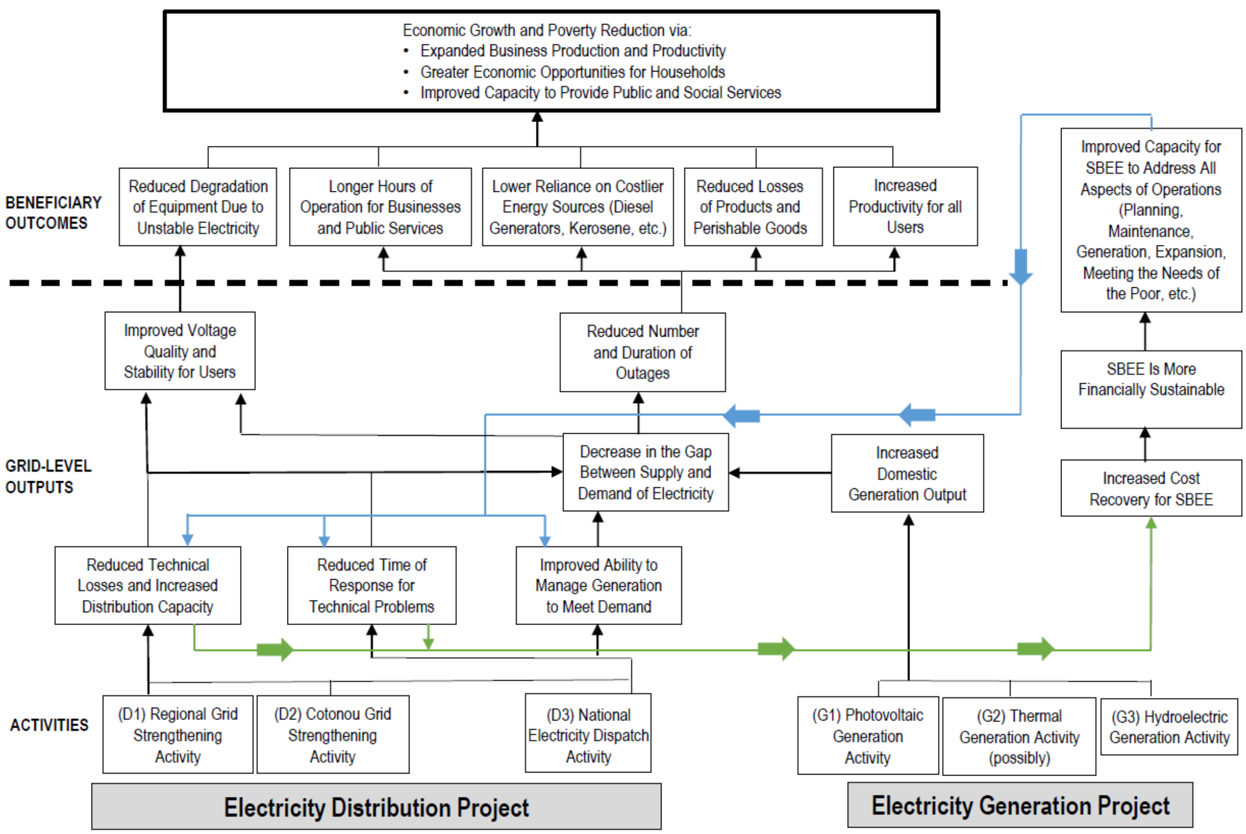
Source: Adapted from Cardno and Fichtner 2015.

Note: This map reflects the network in Benin and Togo as of 2011. Dotted lines represent anticipated construction of lines as of 2011.

B. Overview of the theory of change

The activities planned under the compact are designed to contribute, individually or in combination, to increased economic growth and reduced poverty through the following: (1) expanded business production and productivity, (2) additional economic opportunities for households, and (3) improved capacity to provide public and social services. MCC's compact theory of change (not shown here) shows how each of the four compact projects is expected to contribute to the compact's goals. A detailed theory of change specific to the Electricity Generation and Distribution Projects illustrates the activities, outputs, and medium- and long-term outcomes related to those projects, with the horizontal dashed line separating grid-level outputs from beneficiary outcomes (Figure II.2).

Figure II.2. Theory of change for the Electricity Generation and Distribution Projects



Source: Adapted from "Millennium Challenge Compact" (MCC 2015).

The figure shows how planned activities under the Electricity Generation Project are expected to lead to increased domestic generation output, a decreased supply-demand gap, a reduced number and duration of outages, and improved voltage quality and stability. The figure also shows how, through reduced technical losses, reduced time to respond to technical problems, and an improved ability to manage generation, planned activities under the Electricity Distribution Project may lead to the same grid outputs as the Electricity Generation Project—that is, a reduced number and duration of outages and improved voltage quality and stability.

As discussed in its Evaluability Assessment, Mathematica modified the theory of change slightly from MCC's original version (Bos et al. 2017). In the revised model, reduced technical losses, reduced time to respond to problems, and a decrease in the gap between supply and demand are all expected to contribute to SBEE experiencing increased cost recovery (lines shown in green in the figure). As a result of being more financially sustainable, it is anticipated that SBEE will have improved capacity to address all aspects of the grid. This ability will feed into further improvements in grid outcomes, contributing to fewer technical losses, reduced time to respond to problems, and improved ability to manage generation (lines shown in blue in the figure).

The grid-level improvements associated with the Electricity Generation and Distribution Projects are expected to improve several beneficiary-level outcomes for households and businesses connected to the grid. They include less degradation of equipment, longer hours of operation for businesses and social services, reduced reliance on costlier energy sources, fewer losses of products and perishable goods, and improved productivity.

Several assumptions related to these linkages must hold true for the theory of change to be realistic. The Evaluability Assessment (Bos et al. 2017) includes a discussion of whether the assumptions outlined by MCC are realistic and whether there is evidence that the proposed activities can lead to the suggested outcomes. The evaluation design described in this report will allow us to assess whether some of these assumptions are accurate. For example, a key assumption of both the Electricity Generation and Electricity Distribution Projects is that the infrastructure installed through the compact will be properly maintained and function for its entire lifespan. Through interviews with MCA-Benin staff, SBEE staff, and engineers, Mathematica will assess maintenance practices and expectations for the sustainability of MCC's investments. It is also important to note that there are causal links in the overall compact theory of change that depend on the Policy Reform and Institutional Strengthening Project, such as SBEE's ability to maintain MCC's investments. Thus, even though the evaluation of the reform activities is outside the scope of this evaluation, our analysis will draw on information about the outcomes of these activities.

C. Economic rate of return and beneficiary analysis

As described above, MCC's investment in the Electricity Generation and Distribution Projects is expected to benefit all households and businesses connected to the grid in the project areas through improved electricity supply, reliability, and quality. To determine whether these benefits justify the projects' costs, MCC calculates the ERR of its projects.

The ERR is a summary statistic reflecting the economic merits of an investment. Conceptually, it is the discount rate at which the benefits of an intervention are exactly equal to its costs. The higher the benefits relative to costs, the higher the ERR. When developing the compact, MCC calculated estimates of the ERR of the Electricity Generation and Distribution Projects based on their expected costs and benefits, using data from a nationwide survey measuring household and business willingness to pay for electricity. At the time of the compact signing, the estimated ERR for all compact activities, excluding off-grid activities, was 12 percent. MCC has not yet adjusted the ERR model to reflect changes in the projects' activities (for example, the Electricity Generation Project no longer includes rehabilitation of existing thermal plants).

The ERR is computed using the estimated economic value of the total costs and benefits of each project activity, with benefits aggregated across all beneficiaries. The ERR model for the compact assumes that benefits, in the form of increased electricity consumption, will accrue to each of the three groups to which increased electricity will be made available: (1) consumers connected to low-voltage SBEE lines, (2) consumers who purchase electricity from individuals or businesses directly connected to SBEE lines (the secondary market), and (3) consumers directly connected to SBEE medium-voltage lines. For these beneficiaries, the ERR model calculates the benefit as the consumer surplus—that is, the difference between the willingness to pay for electricity minus the cost of electricity and multiplied by the amount of electricity consumed. The benefits calculations rely entirely on the willingness-to-pay figures derived from a survey conducted in Benin in 2015 (INSAE and UCF 2015), whereas the costs comprise MCC's investment, the GoB contribution, and estimated maintenance costs. The ERR includes the costs and benefits of the Electricity Generation and Distribution Projects, the costs (but not benefits) of the policy reform and technical assistance projects, and MCA administrative and monitoring and evaluation (M&E) costs. It does not include any costs or benefits of the off-grid electricity access activity.[6] The ERR is calculated jointly for the Electricity Generation and Distribution Projects because, given the large costs of generation investments, only the benefits of both projects combined could be expected to produce an ERR that surpasses MCC's threshold for investment. A longer discussion of the assumptions underlying the ERR is included in Bos et al. 2017.

MCC also conducted a beneficiary analysis to estimate who would benefit most from project activities. Beneficiaries are broadly defined as individuals benefiting from increased availability of electricity (MCC 2015). These individuals include all members of affected households as well as business owners. MCC estimates that nearly 2 million households across the country (approximately 10 million individuals) will benefit over the entire lifetime of the project, and that 49 percent of those households live on less than $4 per day per household member.

As part of the evaluation, we will compute the ex-post ERR using updated estimates of benefits and costs across the Electricity Generation and Distribution Projects. This ex-post ERR will permit a comparison to other investments in addition to enabling MCC and other stakeholders to determine whether the projects prove to be a sound investment (by comparing the ERR to the "hurdle rate" of 10 percent). We will work with the MCC economist as s/he develops an updated ERR model based on the revised activities under the Electricity Generation and Distribution Projects. As this updated ERR model develops and it becomes clear which benefit streams are considered, Mathematica will develop a methodology for either updating the ERR by updating the model inputs or developing a separate ERR model. This development may require

[6] The sustainability of the benefits of the Electricity Generation and Distribution Projects is clearly linked to the policy reforms, so although the Policy Reform and Institutional Strengthening Project is implemented separately and is not included in the present evaluation, it makes sense to include the costs of that project in the ERR. However, it would be difficult to link specific benefits to the reform projects. The off-grid project is separate from the generation and distribution projects and is not part of this evaluation, so it is not included in the ERR.

updating the measurements in the model of households’ and businesses’ willingness to pay for electricity through measures collected in the surveys.

III. LITERATURE REVIEW

Most African countries suffer from insufficient electricity supply, degradation of distribution networks, and utilities unable to cover their costs. Half of sub-Saharan Africa's installed generation capacity is produced by just one country—South Africa—and up to 25 percent of the region's generation capacity is no longer functioning (IEA 2014; Eberhard et al. 2011). Not only is sub-Saharan Africa's total capacity of 90 gigawatts (GW) lower than in any other region but, with a population of 970 million people, its production capacity per capita is equal to just 20 percent of Central and South America's and only 3 percent of North America's (Population Reference Bureau 2016; EIA 2014; IEA 2014). Globally, Africa accounts for a smaller percentage of global per capita energy use than it did in 2000 (Africa Progress Panel 2015). Widespread blackouts have become common, even in countries that have substantial generation capacity, such as South Africa, Nigeria, and Ghana (The Economist 2014; Reuters 2015). Data from the World Bank Enterprise Survey show that businesses in sub-Saharan Africa experience 8.3 power outages per month, with an average duration of more than five hours (World Bank 2017a). In response to such outages, many countries rely on emergency power in the form of leases for generation capacity, which are very costly (Eberhard et al. 2011; Foster and Briceño-Garmendia 2010). Indeed, Benin recently installed 150 MW of rental capacity in diesel-powered generators to fill the gap between demand and supply during peak hours (Ksoll et al. 2017).

Another cause of high levels of outages is that transmission and distribution loss rates in sub-Saharan Africa are double the world average, meaning that a significant portion of generated power never reaches consumers (IEA 2014). Technical losses—the physical loss of energy as it is transported from power plant to end user—are around 5 percent in the United States (EIA 2017). In sub-Saharan Africa, estimates of the average total loss rate range from 18 percent, excluding South Africa, to nearly 30 percent (IEA 2014; Tallapragada et al. 2009), although those figures include commercial losses, such as theft or meter failures. Technical loss rates are a function of the transmission and distribution network, and tend to be higher when (1) electricity is transported over long distances at low voltage; (2) lines are overloaded; and (3) demand exceeds the supply from generation, causing lower voltage on the lines (Brown and Sedano 2004; Vaillancourt 2014). Technical losses increase outages when generation capacity is limited and insufficient to meet demand because a portion of available generation is unavailable for consumption by end users.

Outages and network losses are further exacerbated by the degrading infrastructure characteristic of many African countries. Two-thirds of utility managers in 15 African countries reported that aging or badly maintained infrastructure was a major concern (PwC 2015). In Benin, grid rehabilitation has been delayed for years, resulting in above-normal loss rates and voltage drops (Cardno and Fichtner 2014). One major reason for the poor state of infrastructure is the inability of utilities to cover their costs. Even though electricity tariffs are higher in most African countries than in the rest of the world, they still are not high enough to cover the exceptionally high cost of generation in Africa, particularly when utilities resort to emergency power generation (Eberhard et al. 2011). Even where tariffs appear to be cost reflective, theft and nonpayment may erode the full value of the tariff, thus reducing revenue to the utility. Across Africa, officials at utility companies cite the absence of cost-reflective tariffs as the largest barrier to improving electricity access and reliability (PwC 2015).

Partially due to these generation and distribution challenges, the pace of expanding coverage to a large majority of the population has been very slow (IEA and World Bank 2015). In sub-Saharan Africa as a whole, only 38 percent of the population had access to electricity in 2014—a modest increase from 23 percent in 1990 (World Bank 2017b). Electrification rates vary widely across the continent. Whereas 64 percent of the population had access to electricity in Ghana in 2012, only 38 percent had access in Benin, and under 10 percent in Liberia, Malawi, and Burundi (World Bank 2017b). Lack of access to electricity and poor power provision take an important economic toll. The World Bank estimates that sub-Saharan Africa experiences losses equal to 2.1 percent of gross domestic product (GDP) due to power outages (Eberhard et al. 2011). Other studies have found that poor electricity infrastructure hinders foreign investment, business operations, and productivity (Andersen and Dalgaard 2013; Mensah 2016; Escribano et al. 2010).

Recognizing that electricity is a critical component of economic development, improving the supply and quality of electricity has become a key focus of African governments and donors. Energy is one of the 17 Sustainable Development Goals for 2030, with the goal of universal access to affordable, reliable, and modern energy services by 2030 (United Nations 2016). The World Bank, a co-leader of the United Nations (UN's) Sustainable Energy for All Initiative, has provided almost $50 billion in global energy financing since 2010 (World Bank 2017c). The U.S. government announced Power Africa in 2013 as a major initiative to increase access to power in Africa. Twelve U.S. government agencies participate in Power Africa and have committed approximately $9.7 billion through 2018, in addition to an estimated $40 billion from private sector partners (Cook et al. 2015; USAID 2016). As part of this commitment, MCC has funded several electricity projects, including the $375 million compact in Benin (the subject of this report), a $498 million compact in Ghana, a $257 million compact in Liberia, and a $44 million threshold program in Sierra Leone (MCC 2017). Power Africa's goals call for supporting and strengthening institutions, promoting private investment, adding 30,000 MW in electricity generation capacity, and increasing connections among households and businesses.

Given the large magnitude of these investments, it is important to have rigorous evidence on what strategies are most effective in improving the supply and quality of electricity in sub-Saharan African countries. The evaluation of the Benin Electricity Generation and Distribution Projects described in this report will contribute to the evidence on the effectiveness of building and rehabilitating power plants, improving the distribution network, and increasing connections in urban areas. To provide context for the evaluation, we review the existing evidence relevant to the key project activities and anticipated outcomes, as outlined in the projects' theory of change. In the first section of this chapter, we review the literature related to grid-level outcomes, such as generation capacity, voltage quality, system reliability, and technical losses. In the second section, we review the literature related to outcomes for businesses; in the third section, we review the literature on the impacts of electricity connections and improved quality of electricity on household outcomes. We discuss gaps in the literature in the fourth section, as well as contributions of this evaluation in filling many of these gaps.

A. Grid-level outcomes

1. Increased supply of electricity

The Electricity Generation Project is designed to increase domestic generation capacity and narrow the gap between the demand and supply of electricity through the rehabilitation of existing power plants and the construction of new solar power plants.

Although the studies reviewed here cannot rule out other potential factors affecting outages, they nonetheless provide strong suggestive evidence on the outcomes related to power generation projects. 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). After the installation of the new generation capacity, load shedding (planned outages) decreased from 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 to provide power to the population of the Senegal River Basin in Mali, Senegal, and Mauritania, and reportedly eliminated all load shedding in the affected region (World Bank 2006). However, not all World Bank generation projects were as successful. 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). Some of the World Bank electricity generation projects also encountered significant challenges related to cost overruns, extensive delays, and low capacity of the civil works contractors (World Bank 2006; World Bank 2008).

2. Improved electricity quality and reliability

The Electricity Distribution Project aims to improve electricity quality and reliability through grid improvements, such as line replacement, substation upgrades, new switchgear connections, and new electricity lines; new connections; and the creation of a national distribution control center to improve the national utility's ability to provide technical support. A few studies in developing countries have attempted to measure changes in indicators of electricity quality and reliability due to specific grid system improvements; a larger literature has used network simulation techniques to assess changes in technical losses that cannot be measured directly.

An MCC-funded study in Tanzania used a pre-post analysis to estimate the changes in outcomes for hotels in Zanzibar after the installation of a new 100-MW transmission cable. The study found that the estimated number of voltage fluctuations per month, as reported by hotel owners, fell from 56.4 before the new cable to 4.7 afterward (Schurrer et al. 2015). The study also documented a decline in the number of outages per month, from 17.2 outages pre-cable to 10.6 outages post-cable.

The World Bank-funded project in Rwanda cited above also included transmission and distribution system improvements. Over the course of the project period, the system loss rate fell from 25 percent to 16 percent. However, that decline includes both technical and commercial loss rates; thus, it is not possible to distinguish between reductions in technical losses, which would result from improvements in the network, and reductions in commercial losses, which would result from other institutional changes. The challenge of accurately measuring technical losses is a major constraint in the literature on the effects of electricity network improvements.

Many studies in electrical engineering employ simulation software to estimate the effects of a variety of specific grid improvements and document the results of the most promising strategies, estimated through modeling or actual implementation on the grid. For example, a study in India reports on several strategies modeled to reduce losses at specific locations on the grid (Ramesh et al. 2009). After reviewing different options, the study team recommended restructuring the substation and replacing three low-voltage output feeders with five new feeders. The study found that after implementing these changes, losses were an estimated 60 percent lower on the new feeders, according to the electricity network simulation software. Additional simulations also suggested that installation of capacitor banks could reduce losses by 7 percent. In Ghana, a study of the transmission and distribution network demonstrated that high loss rates in the northern part of the country were caused by long distances between power plants and customers, a radial network configuration, and increasing loads on the lines. Capacitor banks whose capacity was determined based on simulations were installed at critical substations to increase the voltage. As a result, the study authors estimated a 3.7 percent reduction in losses in the affected areas, using electricity network simulation software (Owusu et al. 2015).

B. Business outcomes

1. Longer hours of operation for businesses

There are no specific statistics to indicate the extent to which businesses and social services must shorten their hours due to outages, but there are some data demonstrating that outages are a constraint to business operations. A study in Ghana found that firm owners worked fewer hours during blackouts and did not make up for lost hours on days without outages (Hardy and McCasland 2017). The study found that as a result, blackouts had a negative impact on weekly profits and wage expenditures. Survey data from a study in Nigeria in 1998 found that businesses lost an average of 792 working hours during the year, with about 35 percent of firms reporting that they had stopped production at least once during the year because of power outages (Adenikinju 2003). Further, firms reported that the vast majority of their losses resulting from power outages were due to lost output. Small firms suffered the most, reporting that their output loss was equal to 24 percent of their total output, compared to 14 percent for medium firms and 17 percent for large firms. Small firms everywhere are less likely to own a generator and thus are more likely to be forced to close during outages. In Benin, only 35 percent of small firms own or share a generator, compared to 92 percent of medium-size firms and more than 65 percent of large firms (World Bank 2016a). Even those that own a generator may not be able to operate at full capacity or afford to run the generator for the entire period of the outage (Scott et al. 2014).

2. Lower reliance on costlier energy sources

Given the high rates of generator ownership, firms can incur large additional costs for electricity. In Benin, the estimated average total cost for self-generated electricity is about $0.46 per kilowatt hour (kWh), compared to about $0.23 per kWh for grid electricity (World Bank 2016a; Foster and Steinbuks 2009; MCC 2015). Firms are more likely to use a generator and derive a higher percentage of electricity consumption from generators in countries that have frequent power outages (Foster and Steinbuks 2009).

3. Reduced degradation of equipment due to unstable electricity

Unstable electricity—characterized by overloads and voltage drops—is detrimental to electric machinery and equipment (Seymour 2010; Dedad 2008). However, there is little evidence regarding the losses firms incur due to equipment damage caused by power surges or outages. In one study in Nigeria, survey data revealed that, of firms' reported losses due to power outages, about 5 percent resulted from equipment damage (Adenikinju 2003). A study of hotels in Zanzibar found that hotels spent a significant amount of money repairing and replacing equipment damaged by voltage fluctuations (Hankinson et al. 2011). Analysis of the World Bank Enterprise Survey found that firms experiencing outages on more than 60 days per year lost about 1 percent of sales due to equipment failure, compared to 0.5 percent of sales for firms that had outages for fewer than 60 days (Foster and Steinbuks 2009). The same study found that smaller firms lost a greater percentage of their sales due to equipment damage caused by outages than larger firms, likely because they were less likely to own a generator. Nevertheless, these losses were fairly low, representing less than 1.5 percent of sales even for small firms, which are the most affected (Foster and Steinbuks 2009). This evidence suggests that firms have adapted to low electricity availability and do not incur substantial costs due to equipment failure from outages, although smaller firms are more vulnerable to damage than larger firms.

4. Reduced losses of products and perishable goods

There is very little evidence on the impact of poor electricity quality and reliability on product losses. In a study in Nigeria, businesses reported that about 8 percent of their financial losses came from destruction of raw materials during outages, and that these outages lasted for two hours on average (Adenikinju 2003).

5. Increased productivity for businesses

At the firm level, Escribano and colleagues (2010) found that the quality of electricity provision was one of the largest contributors to the average total factor productivity of manufacturing firms in low-income countries. Another study in West Africa found few clear economic benefits of electricity to micro and small informal businesses (Grimm et al. 2013). Overall, the evidence suggests that poor quality and unreliable electricity hampers productivity, particularly for firms in electricity-intensive sectors, such as manufacturing (Adenikinju 2003; Arnold et al. 2008; Escribano et al. 2010). A study of the effects of an increased supply of electricity in West Bengal and Bihar, India is one of the few that attempts to separate increased generation from improved reliability. Using time-series analysis, the study estimated that a 1 percentage point increase in electricity consumption correlated with a 0.53 percent growth in employment. Using data from the World Enterprise Study and information on the increase in energy supplied, the study estimated that the project led to more than 74,000 new jobs in India due to increased electricity supply, and nearly 1,600 new jobs in West Bengal due to a reduction in power outages (IFC Development Impact Department 2012).

C. Household outcomes

1. Lower reliance on costlier energy sources

Several studies discuss the impact of electrification on household energy sources. The findings from them are mixed, however. In a rigorous evaluation of MCC's energy investments in Tanzania using a difference-in-differences approach with a matched comparison group design, Chaplin and colleagues (2017) found no impact from having a household connection on the monthly amount of total liquid or solid fuel use. However, they found that electrified households were 14 percentage points less likely to own a generator, and that electrified households used less non-grid electricity and kerosene, on average, than non-connected households. Even though qualitative evidence from the evaluation suggested that most people found grid electricity to be cheaper than other energy sources, and that outages were not frequent, even electrified households continued to rely on alternative energy sources (Miller et al. 2015). Studies in India and El Salvador found significant reductions in kerosene use due to electrification (Khandker et al. 2012; Barron and Torero 2016); another study in Ethiopia reported that the electrical grid connection available in most connected households allowed for no more than four light bulbs, thus limiting movement away from alternative fuel sources for most household activities (Bernard and Torero 2015). In general, it appears that households use electricity primarily for lighting and television but rarely for cooking (Bernard 2012; Golumbeanu and Barnes 2013); Bernard and Torero 2015; Barron and Torero 2016).

At the household level, there is little evidence regarding the impact of electricity *quality* on alternative fuel use. Descriptively, a number of studies have shown that households with electricity still own kerosene lamps for use when the power supply cuts out (Asaduzzaman et al. 2010; Meier et al. 2010). A study in rural India used a matched comparison group design to estimate the impacts of an electricity connection. The study found that households connected to electricity experienced a 12 percent reduction in kerosene consumption and spent 1.6 hours less per month collecting biomass fuel (Samad and Zhang 2016). When the model controlled for reliability of electricity, the study found a 14 percent reduction in kerosene use and a 3.5-hour reduction in time spent collecting fuel, suggesting that households with imperfect electricity supply continue to rely on alternative energy sources.

2. Improved education outcomes and increased productivity for households

Several studies use rigorous methods to estimate the impact of having or being offered electricity on household-level economic and educational outcomes, again with mixed findings. Some of these studies found that electricity increases female employment (Grogan and Sadanand 2013; Khandker et al. 2012; Dinkelman 2011). Others found no effect of household electrification on household employment or participation in an income-generating activity (IGA) (Wamukonya and Davis 2001; Bernard and Torero 2009). An evaluation of MCC electricity investments in Tanzania found limited impacts of line extensions and low-cost connection offers on IGA operation, paid employment, or annual income. However, the evaluation found that households connected to the grid had higher annual income and consumption, were more likely to operate an electrified IGA, and had higher monthly and annual revenue from IGAs (Chaplin et al. 2017). A number of studies have also found that having electricity increases the amount of time children spend studying per day (Khandker et al. 2009a; Khandker et al. 2012; Bensch et al. 2011), years of school completed (Khandker et al. 2009a; Khandker et al. 2009b; Van de Walle et al. 2015), and school enrollment (Khandker et al. 2009b; Khandker et al. 2012; Van de Walle et al. 2015). Chaplin and colleagues (2017) found that children in electrified households spend more time studying at night but also significantly more time watching television.

Very little quantitative evidence is available on the household-level economic effects of higher quality electricity. Improved quality of electricity may improve households' economic outcomes by increasing the hours household members can operate home-based income-generating activities, improving productivity, or encouraging household members to invest in IGAs in which they otherwise would not engage. In rural India, Chakravorty and colleagues (2014) found that better-quality electricity (measured as fewer outages and more hours per day) led to a 29 percent increase in households' nonagricultural income over a 10-year period. Another study in India found that a one-hour increase in the duration of power outages per day resulted in a 2 percent reduction in nonfarm income and a 0.5 percent reduction in total income, on average (Samad and Zhang 2016). Similarly, power outages decreased both food and nonfood per capita expenditures and increased the poverty rate. These studies suggest that poor electricity reliability has a negative effect on household productivity. Further, given the established evidence that electricity quality is poor throughout sub-Saharan Africa, studies estimating the impact of household connections are likely measuring that of intermittent power supply, thus providing an underestimate of the impact of a reliable electricity connection.

D. Gaps in the literature and contribution of the Benin II Energy evaluation

There are several noticeable gaps in the literature on the effects of electricity generation and distribution investments in sub-Saharan Africa. First, very few studies employ a counterfactual to assess the effect of distribution network improvements on measures of electricity quality and reliability. In fact, none of the studies we reviewed provides rigorous impact estimates, and—except for pure simulation studies—they study only bundled interventions. Similarly, few studies go one step further and estimate the effects of grid improvements on households and businesses. To the best of our knowledge, there are no impact evaluations in developing countries that measure the impact of electricity generation projects on grid-level outcomes, such as power outages. Existing studies typically evaluate a bundle of interventions that includes the effects of additional installed capacity along with other related electricity infrastructure investments and institutional improvements, and provide a simple pre-post analysis that cannot account for other unrelated factors that could influence changes in outcomes over time.

Furthermore, although more evidence is available on the impact of new electricity connections on households, most of this literature is focused on rural areas, where households face markedly different constraints to connecting than in urban areas. One exception is the study by Chaplin and colleagues (2017), which estimated the impacts of access to electricity in both rural and urban areas. Overall, however, it is not clear whether the impacts reported in studies of rural areas would be observed in the urban areas primarily targeted by the Benin compact.

The planned evaluation will fill many of these gaps. It will provide a combination of rigorous and descriptive evidence on each of these areas of research. Specifically, the evaluation uses an interrupted time-series design to conduct two impact evaluations linking increased power generation and specific improvements in the distribution network to (1) grid-level outcomes and (2) outcomes for households and businesses. A pre-post analysis of changes in long-term outcomes for businesses and households will complement the impact evaluations. In addition, we propose an impact study that will estimate the impacts of new electricity connections on household outcomes in urban neighborhoods of Cotonou (described in Appendix A). Finally, the evaluation will also include a qualitative study, enabling us to examine the specific ways in which households, businesses, and public institutions benefit from infrastructure investments.

Combined, this evidence will be of specific interest to donors making investments in electricity as part of their overall development portfolios.

IV. EVALUATION DESIGN

In this chapter, we provide an overview of the evaluation design. In Section A, we link the evaluation's research questions (RQs) to the Electricity Generation and Distribution Projects' theory of change. In Section B, we provide a brief overview of the evaluation strategy, presenting the major themes, the proposed evaluation design, and the data sources.

A. Evaluation questions

Our evaluation is organized around the theory of change presented in Chapter II (see Figure II.2). Specifically, we are testing the causal links (the arrows) in the theory of change to determine whether the activities and inputs of the Electricity Generation and Distribution Projects impact grid-level outputs, and whether any improvements in these outputs result in improved beneficiary outcomes. We divide the evaluation questions into three categories corresponding to the different "tiers" of the theory of change: (1) overarching questions related to implementation and sustainability, (2) questions related to grid-level outcomes or project outputs, and (3) questions related to end users. A full list of the evaluation questions and their links to the program logic is provided in Table IV.1.

Table IV.1. Evaluation questions and links to program logic

<table>
<tr><th colspan="2">Question group</th><th>Theory of change level</th></tr>
<tr><td colspan="3">Overarching questions</td></tr>
<tr><td rowspan="4">RQ1</td><td>How were projects implemented, and what were the implementation successes and challenges?</td><td rowspan="4">Compact activities and outputs</td></tr>
<tr><td>a. What changes occurred to the original design and why did they occur? How did those changes influence the ability of the program to reach its objectives?</td></tr>
<tr><td>b. How well were the projects implemented? Did the way in which they were implemented help or hinder their success?</td></tr>
<tr><td>c. The Distribution and Electricity Generation Projects were intended to be complementary. To what extent was this complementarity maintained through implementation?</td></tr>
<tr><td rowspan="3">RQ2</td><td>What are stakeholders' perceptions of the sustainability of the outcomes achieved through the compact projects?</td><td rowspan="3">Sustainability of grid-level and beneficiary outcomes;
Sustainability of compact outputs</td></tr>
<tr><td>a. To what extent are MCC's maintenance expectations for the new infrastructure works being met?</td></tr>
<tr><td>b. To what extent does SBEE maintain and use the grid-monitoring equipment?</td></tr>
<tr><td>RQ3</td><td>How and to what extent have factors outside of the compact (such as availability of energy imports from Ghana and Nigeria, completion of the North-South 161-kV line, the role of the Communauté Electrique du Benin [CEB], increases in overall demand, and so on) influenced the ability of the projects to meet their expected outcomes?</td><td>Assumptions underlying program logic</td></tr>
<tr><td>RQ4</td><td>What are the estimated benefits and costs, and the ex-post ERR of MCC's investment in the electricity projects?</td><td>Compact activities; Beneficiary outcomes</td></tr>
</table>

Question group		Theory of change level
RQ5	What lessons can be drawn from analysis of the design, assumptions, implementation and delivery, and impact analyses of the Benin II Distribution and Electricity Generation Projects to inform future projects?	Compact activities; Compact outputs; Grid-level outcomes; Beneficiary outcomes; Program logic assumptions
Questions related to program outputs		
RQ6	To what extent did the projects increase domestic energy output and decrease the supply-demand gap for electricity?	Grid-level outcomes
RQ7	What is the impact of compact activities on the reliability and quality of electricity, and on technical losses?	Grid-level outcomes
	a. What, if any, were the contributions of the different project components (NDCC, generation, distribution)?	
	b. How have the above impacts, if any, varied across different portions of the grid—areas where new/rehabilitated infrastructure were installed versus other areas?	
RQ8	To what extent did the response time to technical problems on the grid change after the projects were implemented?	Grid-level outcomes
Questions related to end-user outcomes		
RQ9	What are the impacts of the project activities on business outcomes (output, profits, hours of operations, energy sources, investment in energy-intensive equipment, degradation of grid-connected equipment, spoilage)? How did these impacts vary by type/formality/sector of business?	Short- and medium-term beneficiary outcomes
RQ10	What is the impact of the project on household outcomes (productivity, time use, sources of energy, investment in energy-intensive appliances, degradation of grid-connected appliances, spoilage of perishable food)? Did these effects vary by subgroups (gender, income)?	Short and medium-term beneficiary outcomes
RQ11	To what extent did the outcomes for public/social services (for example, health facilities, schools) change after the projects were implemented?	Short- and medium-term beneficiary outcomes
RQ12	What are the impacts of new connections on household and small business outcomes (as listed under RQ9 and RQ10)?	Short- and medium-term beneficiary outcomes

A few linkages in the program logic are not within the scope of this evaluation. Specifically, the evaluation will not attempt to verify the “feedback loop” that appears on the right side of Figure II.2. In this loop, improved grid performance results in greater financial stability for the utility, allowing it to invest more in grid infrastructure and improvements, resulting in improved service and quality. The financial stability of the utility is outside the scope of this evaluation and will be addressed by the separate evaluation of the Policy Reform and Institutional Strengthening Project.

B. Overview of the evaluation strategy

Mathematica has designed a comprehensive mixed-methods evaluation of the Electricity Generation and Distribution Projects to answer the evaluation questions listed above. Several of them can be answered through rigorous impact evaluations, whereas we will address others through performance evaluations incorporating both quantitative and qualitative data. Two of the quantitative impact evaluations will estimate impacts of the Electricity Generation and

Distribution Projects—separately and in combination—on (1) grid-level outcomes, such as electricity supply, reliability, and quality; and (2) end-user outcomes, such as the energy expenditures of firms and households. To estimate the impacts on electricity supply, reliability, and quality, we will implement ITS analyses of high-frequency data collected from grid monitors placed systematically in the electricity network. To estimate the impacts on outcomes for small, medium, and large businesses, and households, we will implement ITS analyses using high-frequency data obtained from periodic mobile phone surveys. We will complement the ITS analyses with a quantitative performance evaluation (a pre-post analysis) that uses survey data to study how grid-level and beneficiary outcomes change over time. In addition, we propose an optional impact evaluation relying on a randomized controlled trial that tests interventions to encourage low-income households to connect to new electricity lines in Cotonou and rigorously assesses the impacts of electricity access on measures of household well-being. This optional evaluation is described in Appendix A.

Mathematica will supplement the quantitative impact and performance evaluations with a qualitative performance evaluation, which will include an implementation analysis conducted during and after the compact and a qualitative evaluation of outcomes before the start of activities, near the end of the compact, and two years after the compact. This evaluation will use data from document reviews, interviews, and focus group discussions (FGDs) to generate findings on the implementation and sustainability of the Electricity Generation and Distribution Projects, and build on the quantitative data collection by providing additional context through which to understand the quantitative findings on beneficiary outcomes. In Table IV.2, we describe the key outcomes associated with each research question, as well as the data source and type of data we will collect to measure those outcomes.

Throughout the evaluation, Mathematica will endeavor to understand the impacts on key social groups identified in the GSI requirements in the RFP. Although the Electricity Generation and Distribution Projects do not have the same explicit gender components as the Policy Reform and Institutional Strengthening and Off-Grid Electrification Projects, it is still expected that the activities will lead to improvements for women (particularly female entrepreneurs) and other marginalized social groups. In the context of these projects and this evaluation, Mathematica defines social inclusion as the process of ensuring that socially marginalized groups take part in and benefit from the increased supply and improved quality of electricity. The primary socially marginalized groups studied in this evaluation are women and poor households. However, the evaluation will also seek to include a range of age and ethnic groups among its respondents.[7]

As outlined in the RFP, Mathematica will adhere to MCC's Gender Policy and Gender Integration Guidelines by including research questions that address social and gender dimensions and, when possible, by disaggregating impacts by gender, age, poverty, and ethnicity. Our proposed sample sizes have been determined with this disaggregation in mind. Further, our sampling approach will ensure that we survey both male and female household heads and business owners and managers. Finally, our qualitative analyses will include interviews and FGDs with key GSI groups to fully understand the factors affecting benefits from improved electricity supply and quality. In the tables and sections that follow, we do not explicitly mention

[7] We expect much of the variation in impacts across ethnic groups to reflect regional differences in the location of compact investments.

every instance in which GSI groups will be included, but the reader may refer to this section to understand how we will include these groups in the evaluation.

Table IV.2. Evaluation design overview

Evaluation question	Key outcomes/themes	Evaluation method	Data source and type
RQ1. Did the project design change, what were the reasons for any changes, and how well were the activities implemented?	• Project design and changes over time • Implementation plan and changes over time • Implementation successes and challenges • Complementarity of Electricity Generation and Distribution Projects	• Qualitative performance evaluation	• Review of project documents • Interviews with MCA-Benin staff, SBEE staff, Ministry of Electricity staff, and project engineers • Site visits and beneficiary consultations
RQ2. How sustainable are MCC's investments?	• Perceptions of sustainability • Maintenance of infrastructure • Usage and maintenance of grid-monitoring equipment	• Qualitative performance evaluation	• Review of project documents • Interviews with MCA-Benin staff, SBEE staff, Ministry of Electricity staff, project engineers, and members of the Energy Sector Donor Roundtable, and beneficiary consultations • Site visits
RQ3. How have outside factors influenced the project?	• Availability of energy imports • Completion of North-South 161-kV line • Role of CEB • Other government/donor/ private sector energy investments • Increases in domestic energy demand	• Qualitative performance evaluation	• Review of project documents • Interviews with SBEE staff, Ministry of Electricity staff, and members of Energy Sector Donor Roundtable, and beneficiary consultations
RQ4. What is the ex-post ERR of MCC's investments?	• Impacts on beneficiary outcomes • Final project costs	• Quantitative impact analyses • Quantitative performance evaluation • Qualitative performance evaluation	• High-frequency measurement of grid outcomes from grid monitors installed on the distribution system and smart meters • Surveys of households and businesses • Review of project documents, including SBEE and generation company financial information
RQ5. What are the lessons learned?	• Design and implementation plans, changes, successes, and challenges • Impacts on beneficiary outcomes • Impacts on grid-level outcomes	• Synthesis of evaluation analyses	• Mathematica evaluation analyses • Review of compact closeout documents • Interviews with stakeholders

Evaluation question	Key outcomes/themes	Evaluation method	Data source and type
RQ6. To what extent did the project narrow the supply-demand gap?	• Domestic energy generation capacity and output • Demand for electricity	• Quantitative impact analyses • Qualitative performance evaluation	• High-frequency measurement of grid outcomes • Review of SBEE data
RQ7. How did the project impact electricity reliability, quality, and technical losses?	• Outage frequency and duration • Measures of electricity quality • Technical losses	• Quantitative impact analyses • Qualitative performance evaluation	• High-frequency measurement of grid outcomes • Review of SBEE data
RQ8. How did the response time to technical problems change?	• Duration of outages caused by technical problems • Response time to business and household service calls	• Quantitative impact analyses • Qualitative performance evaluation	• High-frequency measurement of grid outcomes • High-frequency mobile phone surveys of businesses and households • Review of SBEE data • FGDs with households • Interviews and FGDs with businesses of various sizes • Interviews with SBEE line staff
RQ9. What are the impacts of the projects on business outcomes?	• Time use/hours of operation/work disruptions • Energy sources and expenditures • Investment in and degradation of electrical equipment • Losses of products and perishable goods • Productivity/revenue	• Quantitative impact analyses • Quantitative performance evaluation • Qualitative performance evaluation	• High-frequency mobile phone surveys of businesses • Surveys of businesses • Interviews with businesses
RQ10. What are the impacts of the project on household outcomes?	• Productivity • Time use • Energy sources and expenditures • Investment in and degradation of appliances • Losses of products and perishable goods	• Quantitative impact analyses • Quantitative performance evaluation • Qualitative performance evaluation	• High-frequency mobile phone surveys with households • Surveys of households • FGDs with households
RQ11. To what extent did the outcomes for public/social services (for example, health facilities, schools) change after the projects were implemented?	• Hours of operation • Usage of electrical equipment • Investment in and degradation of equipment • Perception of electricity reliability and quality • Perception of electricity as constraint	• Qualitative performance evaluation	• Interviews with public institutions and institutions providing social services

Evaluation question	Key outcomes/themes	Evaluation method	Data source and type
RQ12. What are the impacts of new connections on household and small business outcomes?	• Energy use and electricity consumption and expenditure • Adult and child time use (households) • Employment, IGAs, income, consumption (households) • Time use and hours of operation (businesses) • Investment in electrical equipment • Productivity and revenue • Decision to connect and constraints to connecting • Expected and realized benefits of connecting • Improvements in health outcomes (households)	• Quantitative impact analyses • Qualitative performance evaluation	• Surveys of households and small businesses in the household • FGDs with households • SBEE billing records

We will integrate findings from the quantitative impact and performance evaluations, the qualitative performance evaluation, and the ERR into a comprehensive assessment of the Benin Power Compact. Analyzing a wide range of data sources by using a variety of methods will allow us to draw relevant lessons to inform MCC and other policymakers' decisions about similar energy investments in the future.

In the chapters that follow, we discuss the design for each evaluation component separately. We describe the design of the quantitative impact and performance evaluations for grid outcomes in Chapter V, and the design of the quantitative impact and performance evaluations for household and business outcomes in Chapter VI. Finally, in Chapter VII, we summarize our approach for the qualitative performance evaluation. Each chapter describes the methodology, anticipated timing of outcomes, sampling, data collection, analysis plan, and limitations for the given evaluation component. In addition, in Appendix A we outline our proposed design for a rigorous impact evaluation of the impact of new connections in Cotonou.

V. QUANTITATIVE ANALYSIS OF GRID-LEVEL OUTCOMES

To estimate the short-term impacts of MCC's investments in additional generation capacity and distribution network improvements on grid-level outcomes, such as electricity supply, reliability, and quality, we propose to implement an ITS approach. In addition, we propose to conduct a pre-post analysis to understand longer-term changes, along with a descriptive analysis to understand how outside factors might interact with project outcomes.

To measure grid-level outcomes, we will use high-frequency data collected from grid monitors and smart meters placed systematically by the design consultant in the electricity network. Specifically, we propose to collect data at power plants, substations, and locations in the distribution network where MCC's investments are planned and beneficiaries are located.[8] The analysis of these data will allow us to answer MCC's three primary evaluation questions regarding grid-level outcomes: (1) the effects of the Electricity Generation Project on domestic energy output and the supply-demand gap for electricity (RQ6); (2) the effects of the Electricity Generation and Distribution Projects separately and as a whole on the reliability and quality of electricity and technical losses, and whether the projects had different effects in different areas of the grid (RQ7); and (3) the importance of factors outside of the compact (energy imports, increased domestic production, and completion of the North–South 161-kV line) for reducing or amplifying the effects of the Electricity Generation and Distribution Projects (RQ3). These analyses will also inform the qualitative implementation analysis (RQ1) (see Chapter VIII).

This chapter describes the evaluation design for the analysis of grid-level outcomes. In Section A, we describe the methods for conducting (1) the ITS approach and (2) the pre-post and descriptive analysis. In Section B, we review the expected timing of the short-, medium-, and long-term outcomes for both approaches. Section C describes the analysis plan for the ITS and pre-post approaches, and Section D outlines the data sources, including a detailed discussion of requirements for potential placement of grid monitors. In Section E, we describe challenges associated with the study design and data collection.

A. Methods

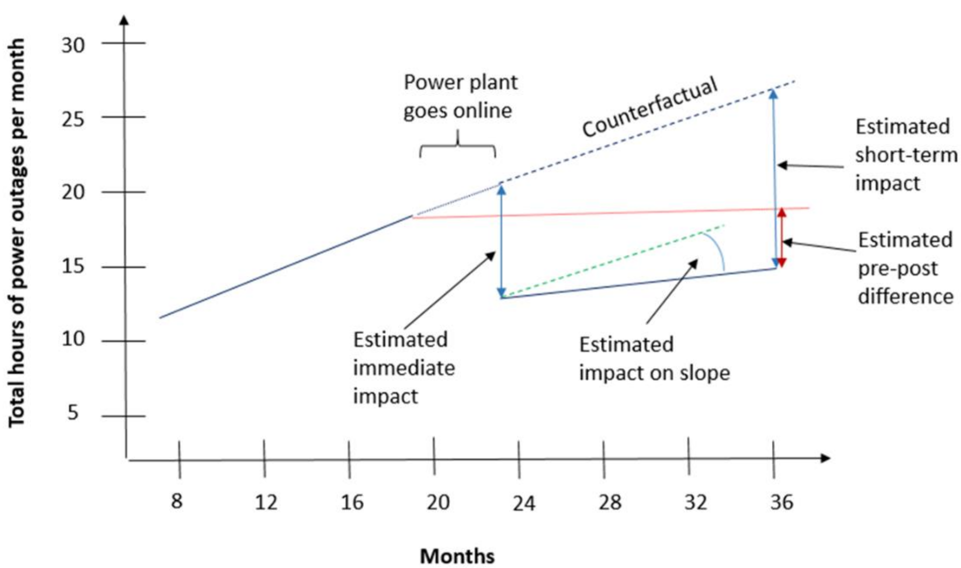
1. Interrupted time-series (ITS) approach.

We propose to rigorously estimate the impact of project activities on electricity generation (RQ6) and electricity reliability, electricity quality, and technical losses (RQ7) by using an ITS approach. This approach estimates the causal impact of a specific project activity—such as constructing a new power plant—by analyzing time-series data before and after the project activity is completed, and assessing to what extent grid-level outcomes change immediately after the completion of the project activity relative to a possible preexisting trend.

[8] Many details regarding the collection of grid data are currently under discussion with MCC, MCA-Benin II, the evaluator, and the design consultant. The information in this section reflects our best recommendations at the time the report was drafted. Decisions on the overall number of monitors and smart meters, their placement in the grid, and their measurement capabilities will affect whether research questions can be fully addressed. Updates and changes will be submitted as part of a memo once the details of the placement and numbers of monitors and smart meters are finalized.

Figure V.1 is a graphical representation of the ITS approach to estimating the impact of a single project activity in one project area. In the hypothetical scenario presented, a new PV power plant in Natitingou becomes operational in the fifth month of the data series. In the period before the power plant comes online, there is an increasing trend in the total number of hours of outages per month, perhaps due to increasing unmet demand in the project area. As the PV plant starts injecting power into the network, the total number of hours of outages per month suddenly drops to a lower level because there is additional electricity supply to meet demand in the project area. In addition, the upward trend in outages due to increasing demand slows: the sufficient supply in electricity leads to voltage levels within the normal range and a subsequent reduction in the likelihood of transformer failure. The data show this effect unfolding over time. A simple pre-post difference would understate the true impact, as it would not account for the pre-intervention upward trend of outages. To predict the number of outages in the absence of the project activity—known as the counterfactual—the ITS analysis relies on frequent observations before the project activity is completed to estimate a possible preexisting trend. The ITS approach relies critically on the assumption that this preexisting trend would have continued over time in the absence of the project activity. In the graph, this assumption is reflected in the continuity between the upward-sloping line in outages before the completion of the power plant and the counterfactual line.

Figure V.1. Interrupted time-series approach



In estimating the impacts of project activities using the ITS approach, we need to account for confounding factors that may affect electricity outcomes. We will account for weekday and time-of-day variations through corresponding indicators. To account for seasonal effects, we will collect at least one year of pre-intervention information and include monthly or weekly indicators.

Aggregation and disaggregation of impact estimates across project activities. The ITS analysis is expected to provide an estimate of the impact of each individual generation and distribution activity, such as the construction of the solar power plant in Natitingou, the upgrade of a monitored transformer in Parakou, or the construction of a specific distribution substation in

Cotonou. As these activities are expected to be completed at different times, they will create an "interruption" in the time series of grid-level outcomes at different points in time and provide an opportunity for us to assess the impacts of each activity separately. In addition, we propose to aggregate the impact of the individual project improvements by project type and geographic area. We will, for example, aggregate the impact of (a) the four PV generation activities to understand the impact of PV generation, (b) all Electricity Generation Project activities (PV, thermal, and hydropower), (c) line improvements, (d) transformer and substation upgrades, and (e) all Electricity Distribution Project activities. We will also aggregate impacts separately across all project activities conducted within each of the five project areas. To provide an estimate for the impact of MCC's investment overall, we also will aggregate across all project activities. Thus, the ITS analysis will provide MCC with clear insights into the combined and separate impacts of the Generation and Distribution Projects, the impact by project area, and the impacts of the individual project activities.

2. Pre-post and descriptive analysis

We will complement the analysis of short-term impacts on electricity generation, reliability, and quality with a longer-term pre-post analysis of the same grid-level outcomes. We will compare outcomes at the end of the compact with those measured during the preintervention period to provide information on the evolution of grid-level outcomes during the period of the compact. We will work with SBEE and the design consultant to ensure that the grid monitors are not removed until they are no longer needed by the evaluation. The SCADA system, once it comes online, will be able to provide all of the information necessary for the evaluation. Using this system, we may also be able to measure longer-term changes in these outcomes.

To determine whether the increase in generation has reduced the supply-demand gap (RQ6), we propose to conduct a mixed-methods analysis that includes the pre-post design and the qualitative analysis described in Chapter VII. We will rely on a pre-post design to capture the medium- and long-term responses to increased generation. In the medium and long term, users are likely to modify their usage behavior and invest in more electricity-intensive equipment as a result of the reduction in the frequency of outages, thus increasing demand for electricity. If the demand increase is substantial, the supply-demand gap might not decrease very much in the medium term. To assess behavioral changes, we also will rely on the qualitative analysis described in Chapter VII. Behaviors will likely vary by gender and socioeconomic status, so GSI disaggregation will be incorporated into this analysis to the extent that it is relevant and possible to do so.

To answer the research question about whether outside factors have reduced or amplified the effects of compact investments, we will rely on a mixed-methods approach that combines descriptive and qualitative analyses. The descriptive analysis will first assess the extent to which outside factors are influencing grid-level outcomes in the project areas for MCC's investments. For example, we will be able to measure the increase in the supply of electricity at the national level resulting from diesel generators rented by the government. The observed substantial increase in rental generation capacity would likely reduce the impact of MCC's generation investments on the supply-demand gap but increase the value of the distribution investments. The evidence from this descriptive analysis will inform the qualitative investigation.

B. Outcomes and their anticipated time frame for realization

1. Short-term outcomes

The ITS approach is best suited to analyze effects on outcomes that can change quickly due to the intervention. It is less well suited to understand the effects on outcomes where we would expect a long delay in a change in outcome. Thus, we propose to use the ITS approach to address the research questions related to program outputs. Specifically, we propose to collect and analyze data on measures related to (1) electricity generation, (2) electricity reliability, (3) electricity quality, and (4) technical losses.

a. Electricity generation

We propose to measure total electricity generated from the PV, thermal, and hydropower plants in megawatt hours (MWh). For the new power plants (the PV and possible thermal power plants), the preintervention electricity generation would be zero, so the postintervention electricity generated would be equivalent to the estimated impact.

In addition to electricity generation, we also propose to calculate the capacity factors (the amount of actual power produced over a given time period relative to a hypothetical situation in which the power plant produces electricity for 24 hours a day at full installed capacity for this same time period) for the solar PV plants. The capacity factor in the U.S. for PV plants is estimated at 20 percent (Bolinger et al. 2016), which reflects lack of sunlight during the night, cloud cover, and the reduced power generation when PV cells are not directed toward the sun during parts of the day.

b. Electricity reliability

For electricity reliability, we propose to measure outages (for example, the number of outages and outage duration) and compute the System Average Interruption Frequency Index (SAIFI) and the System Average Interruption Duration Index (SAIDI), two common reliability indicators used by electric utilities in developed countries. Specifically,

$$(1) \quad SAIFI = \frac{\sum \lambda_i}{N}$$

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

$$(2) \quad SAIDI = \frac{\sum O_i}{N}$$

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.

Utilities in developing countries are often unable to compute SAIDI and SAIFI because they are not able to link electricity customers to the transformers and substations from which they receive electricity, and thus cannot determine the number of users affected by an outage. We propose to make this link in two ways. First, as part of our sampling strategy for the end-user data collection we describe in Chapter VI, we plan to link data from enumeration areas from the

2013 Benin census to the geographic area served by a transformer, which we refer to as the transformer distribution area. Because the boundaries of the enumeration areas and those of the transformer distribution areas will not be the same, we will estimate population numbers in transformer distribution areas based on the share of the enumeration areas they cover and the population of these areas. The key item from the national census that will allow us to compute SAIDI and SAIFI is a question on the main source of lighting, allowing us to determine how many households used electricity for lighting. We will validate and update findings from the census data using end-user data collected as part of a listing exercise of households and small businesses in transformer distribution areas. The listing exercise will provide updated information on the number of connected households and small businesses as of 2017. The advantage of this information is that we will also be able to ask whether households and businesses are directly connected to the grid or receive electricity via a secondary connection.

We will also estimate unmet demand due to outages. To do so, we will estimate the energy demand profile in the absence of outages to determine unmet demand for the time of day and day of week when an outage occurred. Specifically, we will predict the hypothetical electricity demand during the time of the outage based on a regression that uses data on time periods before and possibly after the outage when no service interruption occurred, and that accounts for time-of-day and day-of-week effects. We will disaggregate this measure by type of customer (households versus small businesses).

We propose to collect information on the *type* of outage—planned outage, unplanned outage, load shedding—through outage tracking and maintenance logs. Currently, the design consultant is not proposing to collect information on load shedding or outages due to repairs. This information is crucial; if it is available, we will also be able to disaggregate SAIDI, SAIFI, and the value of unmet electricity demand due to outages across the network by the three types of outages. We are currently working with the design consultant to develop the data collection plan; any changes from this report will be reflected in accompanying memos.

c. Electricity quality

Regarding electricity quality, we propose to measure (1) voltage, (2) undervoltage, (3) overvoltage, and (4) harmonic distortions and voltage fluctuations. The grid monitors and smart meters will measure voltage at regular intervals. In addition, they will record the number and duration of instances in which the voltage was below or above the acceptable voltage level, as defined by the regulator. In Benin, undervoltage and overvoltage are defined as 10 percent below and above 230V, respectively. The equipment will further record whether the undervoltage or overvoltage was extremely low or high—that is, at levels considered damaging for various types of equipment. Finally, if the grid monitors and smart meters have sufficient capacity, we will also measure harmonic distortions in the electric current, which occurs when the current does not vary smoothly with a sine wave.

d. Technical losses

Technical losses are measured as the difference between energy fed into a network and energy delivered to various points. Such losses, which relate to the physics of moving energy around a network, occur along lines and at various components at different levels of the grid. We propose to use different methods to measure technical losses. These methods depend on the level of the grid, the complexity of the distribution network, the availability of data from grid monitors and smart meters, and existing information on the performance and specifications of lines and transformers.

We will be able to measure technical losses using grid monitors in a very limited set of cases. Measurement of actual technical losses is possible only when we have exact measurements of power fed into a network and power delivered—for example, along the 161-kV transmission lines between Djougou and Natitingou. In other cases, where we have reliable information from SBEE on total power delivered to end users in a distinct distribution network, such as in Natitingou, Parakou, or Djougou, we will assess total system losses, consisting of technical and commercial losses. Total losses would be estimated only in limited cases, and likely only for certain distribution networks. Total system losses are calculated by comparing power fed into a distribution network and the total power delivered, as recorded by SBEE's customer billing.[9] Technical losses within a distribution network will be estimated through a spreadsheet model used by SBEE. This model calculates technical losses based on the technical specifications of the lines and transformers within a distribution network. Technical losses from each line and transformer are aggregated across the distribution network in proportion to the share of power delivered to each transformer.

2. Medium- and longer-term outcomes

Using a pre-post design, we will investigate the changes in electricity generation, electricity reliability, electricity quality, and technical losses over the medium and long term using the same short-term outcomes described in the previous section. In addition, we will use a pre-post analysis to investigate changes in the supply-demand gap, as there is likely to be both medium- and long-term responses. To calculate the gap between supply and demand, we will rely specifically on outages that can be identified as due to load shedding, as they are a clear example of supply being insufficient to meet demand.

C. Analysis plan and statistical power

1. ITS approach

As mentioned earlier, we plan to estimate the short-term changes in key outcomes due to program investments using the ITS design. Following best practices for applying the ITS method (Bernal et al. 2017; Somers et al. 2013), we will assess the plausibility of four assumptions we must make to produce valid estimates of program impacts and discuss possible solutions:

- **There are no other changes occurring at the same time or close in time to the intervention under study.** We will begin with a graphical representation of the outcomes with respect to the timing of the intervention. This visual investigation is a useful tool to assess whether there is evidence for other changes that may have occurred shortly before or after the intervention under study. This visual inspection will complement a qualitative analysis of other changes based on documentation from the Ministry of Energy, SBEE, and other donors. Because this is the only assumption that we would not be able to address

[9] Calculating total system losses in this way requires that customers can be linked to the substation that serves them with electricity. In addition, the calculation must take into account prepaid customers and public lighting.

through various statistical methods, we will pay close attention to obtaining timely information on such changes and other projects.

- **There is no preintervention trend in the outcome, a linear preintervention trend, or one that can be linearized through the inclusion of polynomials.** The visual inspection of the data will suggest whether there may be a trend and whether that trend can be transformed to be linear (Bernal et al. 2017). If the data so indicate, the analysis will include a linear trend or polynomials in time, respectively.
- **There are no seasonality effects.** To assess whether there are seasonality effects, such as month-of-year, holiday, or day-of-week effects, we will conduct a regression of preintervention outcomes on indicator variables for the month of the year, the day of the week, and the time of the day on which the measurement was taken, and provide a joint test of whether these indicator variables are jointly significant. If seasonality effects exist, the analysis will include covariates to account for seasonality. However, to do so, the analysis will require at least one year of preintervention outcome measurements (Wagner et al. 2002).
- **There is no autocorrelation in the outcomes.** We will study whether there is any autocorrelation in the residuals from this regression by conducting a Breusch-Godfrey or Durbin-Watson test. When autocorrelation is present, it biases the estimated standard errors. In this case, we would present standard errors estimated following the Newey-West procedure (Linden 2015).

a. Impact analysis

In the absence of evidence of other programs or changes occurring at the same time, we would proceed to implementing a segmented regression analysis using the following ordinary least squares specification, where we address the possibility of a time trend—which we assume is linear for this presentation—seasonality, and autocorrelation (Wagner et al. 2002):

$$(3) \quad y_{ft} = \alpha + \beta * time_t + \gamma * post_t + \delta * timepost_t + W_t{}'\theta_w + Z_f{}'\theta_z + \varepsilon_{ft}$$

where y_{ft} is the grid-level outcome of interest measured at transformer *f* at time *t*; $time_t$ is the time since the start of the data collection, $post_t$ is a binary indicator equal to one for the period immediately after the introduction of a specific project activity—such as the point at which the solar plants start providing electricity—and zero otherwise; $timepost_t$ is the time since the specific project activity was taken online; W_t includes indicators to account for temporal patterns of usage, such as monthly (or day-of-year), day-of-week, and time-of-day effects; Z_f includes baseline characteristics specific to the transformer- and transformer distribution area; and ε_{ft} is a random error term that exhibits autocorrelation. The coefficients of interest are γ and δ, which provide estimates of the impact of project activities on the level and the slope of the outcome due to introduction of the project activity. If necessary, the estimated standard errors will account for autocorrelation (Linden 2015).

When there are multiple project activities that come online, the segmented regression can be modified as follows:

$$(4) \quad y_{ft} = \alpha + \beta * time_t + \gamma 1 * post1_t + \delta 1 * timepost1_t +$$

$$\gamma 2 * post2_t + \delta 2 * timepost2_t + \cdots +$$
$$+W_t{}'\theta_w + Z_f{}'\theta_z + \varepsilon_{ft}$$

Describing the use of ITS in education settings, Somers et al. (2013) suggests that, at a minimum, data from three points in time should be available before the introduction of project activities to estimate short-term impacts, and four points in time to estimate longer-term impacts, though recommendations in other fields suggest that observations from 12 points in time before and after the introduction are preferable. Because the grid monitors can in principle provide measurements for every fraction of a second, we will have access to observations from a sufficiently large number of times before and between the introduction of each project activity, and between the introduction of project activities and the time periods beyond their completion.

To estimate the average impact of multiple project activities of the same type—for example, the average impact of PV generation in the northern project areas—we will estimate a restricted least squares model, where we would impose the restriction that the estimated impact coefficients for the three PV plants be the same. For example, if the PV plants are the first three projects to come online, the restriction we would impose to estimate the average impact of the PV power plants immediately after they come online would be $\gamma 1 = \gamma 2 = \gamma 3$, and the estimates from the restricted least squares model would indicate the average impact of the activities. In order to estimate the total effect of multiple project activities that are not similar to each other, for example when beneficiaries benefit from generation and distribution activities, we would add together the respective impact estimates.

b. Statistical power

Table V.1 presents illustrative minimum detectable impacts (MDIs) for the ITS design for two outcomes measured at the transformer level—the percentage of transformers with overvoltage, and undervoltage as measured by the average reading from smart meters placed at end users clustered within the transformer's distribution area. Although our proposed analysis will also analyze data from grid monitors placed at substations, power plants, and along electricity lines to measure technical losses, we do not have the necessary outcomes data to estimate MDIs for these other possible grid monitor locations. We present results for three illustrative sample sizes that could capture MCC's interventions for subsets of project activities: (1) a sample size of 40 monitored transformers, which could provide a representative picture of the impacts of distribution project investments in a project area such as Natitingou; and (2) a sample size of 10 monitored transformers, which could provide a representative assessment of the impacts of new generation activities across all project areas. We believe that at a very local level we would have sufficient power to detect only very substantial changes in the percentage of overvoltage or undervoltage, at about 3.4 percentage points or up to 25 percent of the baseline mean. We believe these changes may not be feasible for most investments, such as replacement of nonfunctioning equipment. For most investments, we will have sufficient power to detect impacts only after the aggregation of multiple investments. The final number of grid monitors and smart meters, and their placement, are currently being discussed with the design consultant. Final details, including on the number of grid monitors, their locations, and the suggested number of smart meters, will be reported in a separate memo.

We note that the MDI calculations are subject to some uncertainty because we do not have a realistic sense of the variability of the data from prior assessments or data collections, and we cannot provide power calculations for measurements at the substation or power plant levels. The information upon which we would rely comes from the 2016 SBEE transformer census and provides a measure of the average voltage for a transformer over a period of time. To gain a sense of the quality of electricity, we would then calculate whether this average hourly voltage is outside of the acceptable range for voltage. For an ITS analysis, the relevant information would be the variability *across* time for a specific transformer and whether at any point in time the voltage is outside of the acceptable range.

The number of transformers used for the MDI calculations in Table V.1 will allow us to estimate project impacts for a subset of project activities. The different sample sizes proposed are meant to illustrate the trade-off between estimating impacts of projects expected to have very localized benefits and those that would benefit a larger area. Because MCC's investment covers multiple project activities in multiple project areas, the transformer sample sizes presented here will not provide a picture of the overall impacts of the Electricity Distribution and Projects, which would require grid monitors and smart meters to take measurements covering all project activities.

Table V.1. Minimum detectable impacts for grid-level outcomes under the ITS design

Analysis unit	Evaluation design	Transformer sample size	Outcome	Baseline mean	MDI	MDI (% change from mean)
Grid monitor	ITS	40	Percentage of hourly measurements that are overvoltage	13.7	0.5	4.0%
Grid monitor	ITS	10	Percentage of hourly measurements that are overvoltage	13.7	1.1	8.0%
Grid monitor	ITS	40	Percentage of hourly measurements that are undervoltage	20.5	0.6	3.1%
Grid monitor	ITS	10	Percentage of hourly measurements that are undervoltage	20.5	1.3	6.2%

Notes: We assumed a confidence level of 95 percent, two-tailed tests, 80 percent power, and 1,000 observations before and after the intervention, which corresponds to one observation every hour for 40 days before and after the intervention. We do not expect sample attrition. We assume autocorrelation of 0.2 and that preintervention characteristics of transformers explain 20 percent of variance. We calculate percentage of extreme voltage based on data from the 2016 SBEE transformer census that captures average levels of voltage over the undefined period of measurement (SBEE 2017).

2. Pre-post analysis

To estimate the long-term changes in grid outcomes over time, we will employ a pre-post analysis. This analysis compares the level of an outcome at a given point in time after the intervention to the level of that outcome before the intervention. We will use a regression model of the following form:

$$(5) \quad y_{gt} = \alpha + \beta * post_t + \varepsilon_{gt}$$

where, for the analysis of the grid-level outcomes, $y_{gt}$is the outcome of interest grid-monitor f in year t (baseline or follow-up); and $post_t$ is a binary indicator equal to one at follow-up and zero in the baseline year. The coefficient of interest is β, which gives the average pre-post change in the outcome.

D. Data sources

The main source of data we will use will come from grid monitors and smart meters systematically placed by GOPA-Intec, the design consultant, on the network and at customer premises; thus, our analysis will rely critically on the availability of grid monitors and the feasibility of placing smart meters with a cluster of end users within a transformer catchment area. Because it would be too costly to monitor all locations in the grid that benefit from MCC's improvements, we propose to sample from strategic locations to obtain a representative picture of the impacts of project activities. In this section, we outline the general process for determining where to place the grid monitors and smart meters. More details on grid monitoring and sampling can be found in a separate series of memos reflecting our discussions with MCA-Benin II, MCC, and the design consultant. Here we (1) provide a description of a simplified electricity network and the potential locations for grid monitor and smart meter placement, (2) describe additional considerations that add complexity to the placement of grid monitors and smart meters, and (3) discuss data collection activities for both grid monitor and smart meter data, and complementary data from SBEE.

1. Placement and measurement on a simple network

Figure V.2 presents a simplified electricity network. A single electricity generation facility (1) generates electricity that then is transmitted via high-voltage transmission lines (2) to a substation (3). The substation steps down the high-voltage electricity from the transmission lines to medium-voltage (MV) levels. Electricity is usually transferred across long distances through high-voltage lines to reduce technical losses. Because MV lines (4) do not require the same clearance from buildings and other installations—and because they are cheaper—they are preferable for distributing electricity to neighborhoods within a city and to rural areas. Transformers (5) step down electricity to 220–240 V in urban areas, and the electricity is transported via low-voltage lines (6) to the end user.[10]

[10] MV customers connect directly to the MV lines. In rural areas, low-voltage lines often operate at 400 V to reduce technical losses and require another step down at the household.

Figure V.2. A simplified electricity network

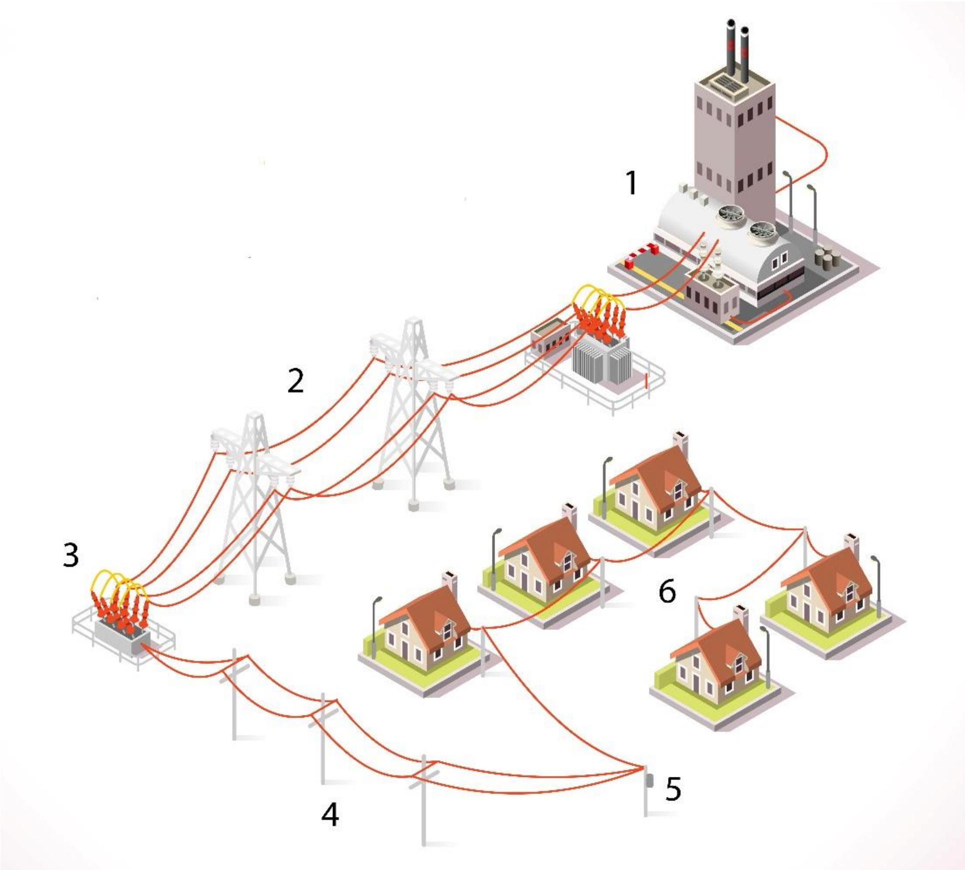


Table V.2 provides an overview of the points on the grid that could be monitored (the first column) and the approximate number of such locations across the country (the second column). We expect to update this information with the number of locations within each project area in collaboration with MCA-Benin and SBEE. The third column in the table lists the type of measurements we propose to take at the various locations in the network. We also include information on smart meters, which can take measurements for a subset of grid-level outcomes directly at end-user premises and be aggregated to estimate the performance of specific transformers.

The hierarchical structure of the grid creates a trade-off when deciding the level at which grid performance should be measured: a placement closer to end users (at a transformer, for example) captures more of the problems that occur in the distribution network, but for a smaller number of end users than if grid performance is measured at transmission substations. The optimal placement also will depend on the nature of MCC’s upgrades to the distribution network, which differ by project area. We conduct the sampling of locations in consultation with the design consultant for the compact, SBEE, MCA-Benin, and MCC.

Table V.2. Grid monitors: Possible placement locations and measures

Location	Potential number of placements	Measure
Grid-monitoring equipment		
Power plant	15–20 by compact end	Generation capacity factor
Distribution substation arrival	41 plus new substation arrivals	Load Reactive energy Outages Voltage Overvoltage and extreme overvoltage Undervoltage and extreme undervoltage Harmonic distortions Voltage fluctuations
Distribution substation infeed into distribution network	120, plus new substation infeeds	
Cabin transformers[a, b]	789	
Pole-mounted transformers[b]	1,386	
Smart meters		
Customer premises	SBEE customers in project areas May require different smart meters for MV, industrial, and domestic customers	Consumption Load Reactive energy (for MV and industrial customers) Outages Voltage Overvoltage and extreme overvoltage Undervoltage and extreme undervoltage

[a] In addition to substations and transformers, the electricity network in Benin also counts a number of distribution posts that may have multiple MV arrivals and departures, as well as feeds into the low-voltage lines. Depending on the function at their specific placement, these distribution posts may be sampled like cabin transformers.

[b] We do not propose placing grid monitors at transformers but have included them in the table to illustrate the full hierarchy of the network.

2. Additional considerations for grid monitoring

The network described above (in Figure V.2) is a representation of a radial network, with a single path for a customer to receive electricity. End users served by radial networks suffer from outages for maintenance or the failure of any equipment between the power plant and the customer. To avoid frequent service interruptions, electricity networks often build in redundancy to allow electricity to flow to the same location along alternative paths. For example, a loop is created when two MV lines exiting a substation connect. Circuit breakers along the loop can be used to partition the loop into radial lines of different lengths. In case of a problem on one infeed, the loop can be reconfigured so that customers receive electricity through the other infeed. The simple radial network is an accurate representation of rural networks in Benin and is sufficient to understand the simpler urban networks of Djougou and Natitingou, which have relatively few loops. (Figure C.1 in Appendix C presents the updated distribution schematic for Natitingou, with the planned extension.) However, a radial network is a poor representation of the distribution network in larger urban areas, such as Parakou and Cotonou, where loop configurations are more prevalent (Appendix Figure C.2, a network schematic of Parakou, illustrates the difference between it and the simpler network of Natitingou.)

One substantial advantage of smart meters over grid monitors at the network level is that smart meters reflect end-user experiences and incorporate all types of upgrades to the entire electricity network. Moreover, when SBEE reconfigures the network, it does not create a measurement problem for smart meter measurements.

a. Loop configurations

The distribution networks of Parakou and Cotonou pose additional challenges for measurement because they already have many loop configurations, and a large part of MCC's investments will result in the creation of new loops (for example, through distribution substations). Unless all substation infeeds are monitored, a loop configuration creates a challenge in interpreting a zero load on one infeed: this circumstance could signal a service interruption because of technical problems or load shedding, or the entire loop may be fed from the other infeed, with no service interruption occurring. The addition of new distribution substations alters existing substations' distribution areas, which creates challenges for linking improvements at the substation infeed to improved customer experiences. Complex networks thus require sampling at a level closer to customers—that is, at the transformer or the customer level. Due to the technical challenges involved in placing grid monitors on pole-mounted transformers, we describe the use of smart meters below.

c. Smart meters

Smart meters are electricity meters that can send information or receive instructions from the electricity utility as part of AMI. AMI and smart meters are common in developed countries but are used in Africa as well. For the evaluation of the Benin Energy Compact, GOPA-Intech has developed a proposal for specific smart meters to measure the quality and reliability of grid electricity experienced by end users. GOPA-Intech has proposed developing a system to measure the following indicators (GOPA 2017):

- Electricity consumption
- Loads above a certain threshold
- Average voltage over a defined period
- Instances in which the average voltage is above a voltage-swell threshold or an extreme overvoltage threshold
- Instances in which the average voltage is below a voltage-sag threshold or an extreme undervoltage threshold
- Outages

To collect the data, GOPA-Intec has proposed setting up a central data management system that collects data automatically.

The installation of smart meters as part of the evaluation presents one significant challenge. Installing them in the sampled businesses and homes requires close coordination with SBEE, as well as customer buy-in in case the meters are installed in locations with existing SBEE meters. At the same time, MCA-Benin has noted that the installation of a smart meter system provides significant learning opportunities for SBEE.

Meters will be placed with end users either by sampling from catchment areas served by transformers or by census enumeration areas. In practice, a number of catchment areas or census enumeration areas will be selected at random and individuals will be selected from within the areas to be monitored.

d. Estimating technical losses

Placement of grid monitors will also affect our ability to measure technical losses. Broadly, we will measure technical losses (1) along the transmission line between Djougou and Natitingou, (2) within urban distribution networks, and (3) along the 63-kV distribution lines within Cotonou.

- **Technical losses along the transmission line between Djougou and Natitingou** can be measured by the difference between power sent by the Djougou substation and that received by the Natitingou substation. Natitingou is located at the end of a 161-kV line originating in Djougou; there is no other point of exit along this line.
- **Technical losses within urban distribution networks** must be estimated because it is not possible to collect data on power delivered to all customers. We will use information from monitors on infeeds and from SBEE's transformer census. Losses are also likely to vary significantly due to daily fluctuations in demand, especially in Cotonou, where the density of customers is greater. Because these data can only be collected by SBEE, we will work with SBEE and MCA-Benin to gather estimates of technical losses that rely on using information on the types of transformers and their capacity to estimate the power delivered to each point in the network as a function of daily demand profiles, seasonal variation, and differences across types of customers served by the transformers' distribution areas.
- **Technical losses along the new 63-kV distribution lines within Cotonou** can be measured by comparing differences in power sent from key step-down substations, such as Vedoko, with power delivered to various distribution substations along the network. However, if new substations are added to the 63-kV network, we may face challenges in estimating technical losses. If we are unable to estimate losses using monitors—for example, because we do not monitor all arrival and exit points—we will create estimates using the physical properties of the lines. We will use this information to assess the performance of the newly reconfigured distribution network.

3. Data collection

Grid monitor and smart meter data. We are working closely with the design consultant to choose the placement of the grid monitors and smart meters, and define the parameters for data collection and data uploading. After the installation of grid monitors and smart meters, it will be the responsibility of the design consultant to make sure the monitors continue to function and transmit data on a daily basis. Mathematica's primary role will be to monitor the stream of data on a regular basis.

SBEE data. GOPA-Intech has proposed setting up a system to obtain information from SBEE on the reasons for unplanned outages. We will not know whether outages are due to planned maintenance or load shedding, however. This information will be important for better understanding the mechanism behind observed improvements in grid outcomes—specifically, to understand the value of different types of improvements for beneficiary outcomes. To determine the quality of the outage data—if these data are available—we will cross-check SBEE's records of outages with the data from the grid monitors and smart meters to match the outages based on time and duration. Regular collection of such secondary data will require significant buy-in from SBEE, not only at the national level but also at the regional and local levels, where the data are likely to be collected. In addition to the information collected by GOPA-Intech, we will collect data on a quarterly basis from SBEE on outside factors, such as projects by other donors that come online. We will collect information on the location, exact date, and type of these other improvements to the grid.

E. Challenges

1. **Other improvements will occur during the compact period, making attribution a challenge.** These other improvements will make it challenging to attribute observed changes to MCC's investment. If the other improvements go online or occur at the same time as investments in Electricity Generation and Distribution Project activities, they can invalidate the ITS design. Mathematica will rely on MCA-Benin to keep track of outside investments in the energy sector and monitor any projects that may affect beneficiaries in our project areas. Mathematica will work with MCA-Benin to establish procedures for sharing this information. In this way we will know if other improvements occur during the compact period. We then would adapt the regression equation to include an additional indicator for the outside treatment—along the same line as how the regression for multiple project activities addresses the issue of estimating the impact of more than one MCC project activity. If an outside improvement is switched on very close to the time MCC project activities are taken online, we will not be able to disentangle the two and separately identify the impact of MCC's investment.
2. **Relevance of grid monitor and smart meter placement depends on accuracy of information on the location of project activities.** It is possible that not all locations initially identified will benefit from the project activities if project plans change. This is a challenge that affects the analysis of grid level and end-user outcomes. We will design a sampling strategy that is robust to some changes in project locations and will work closely with MCA-Benin to determine the optimal timing for grid monitor placement.
3. **Delays in installing grid monitors and smart meters would lead to insufficient preintervention data.** Electricity demand and supply fluctuate during the year due to the weather; the ITS needs to account for this phenomenon through sufficient preintervention data. For example, during the dry season, supply is low as the water reservoirs used for hydropower generation become depleted, whereas demand is high as temperature levels rise, leading to increased use of fans and air conditioning. To account for these seasonality effects, the ITS approach requires at least one year of data before the intervention (Wagner et al. 2002). Given the complexity of the task of installing the grid monitors and setting up the grid monitor data management system, we recommend starting the process for grid monitor placement as soon as possible to ensure they are in place a year before the first improvements go online. Our MDI calculations correspond to the case where we do not have a year of preintervention data. Specifically, we assume that 40 days of hourly preintervention measurements are available which would allow us to account for day-of-week and time-of-day effects. We choose 40 days before and after the intervention in order to reduce possible biases arising from seasonality effects, but this short time frame may not

remove all bias due to annual seasonality effects. If a year of preintervention data is available, we will be able to account for annual seasonality effects. In addition, the ITS analysis will also include measurements from a longer time frame before and after the intervention leading to smaller MDIs.

4. **The information on transformers is limited and network schematics need to be frequently updated.** SBEE has provided us with a census of transformers conducted in 2016–2017, but this information allows for only a partial link with the network schematics because transformer names do not always link the census and the network schematics. The census is also lacking information on whether an area is a commercial district, a residential neighborhood, or mixed. In addition, we have only partial information on the planned geographic locations of grid-level improvement. All of this information is necessary to identify the optimal placement locations of the grid monitors and smart meters. We also need information on areas’ commercial/residential mix to implement oversample areas with a high density of businesses. We plan to continue to work with the design consultant, MCA-Benin, and SBEE to gather this information. There is a risk, however, that SBEE may be unable to provide such information, the data will be of poor quality, or some of the required information will not exist.

5. **Grid monitors may be installed in the wrong locations or non-randomly**, preventing us from gaining a representative sample of infeeds and arrivals. Estimating the average performance of the distribution networks requires a representative sample. We need to be sure that each arrival point and infeed has a positive, known probability of being selected for observations. If other priorities govern the placement of all monitors, it will not be possible to estimate the average performance of the distribution networks being improved.

   Smart meters may be a good option for collecting data on electricity supply, consumption, reliability, and quality for the purposes of the evaluation. We propose to measure the performance of transformers using smart meters placed with end users. This approach will require the installation of smart meters and consumer buy-in as well as a data management system. We will explore possible options with MCA-Benin, SBEE, and the design consultant.

VI. QUANTITATIVE ANALYSIS OF END-USER OUTCOMES

Mathematica will use an ITS design to estimate impacts of the Electricity Generation and Distribution Projects on outcomes for small, medium, and large businesses,[11] and for households, and a pre-post analysis to understand changes in longer-term outcomes for small businesses and households. The ITS analysis will leverage high-frequency data collected using mobile phone surveys from beneficiaries in all project areas to answer research questions on the response time to technical problems (RQ8) and the separate and combined impacts of the Electricity Generation and Distribution Projects on business and household outcomes (RQs 9 and 10). The pre-post analysis will complement the ITS and provide information on changes over time in household and business outcomes (RQs 9 and 10), as measured through a survey administered in person to households and small businesses.

In this chapter, we describe the design of the ITS and the pre-post analysis for end-user outcomes. In Section A, we describe the methods for (1) the ITS approach and (2) the pre-post approach. In Section B, we then define the outcomes and their expected timing. Section C provides an overview of the analysis plan and statistical power, Section D summarizes the data sources, and Section E reviews limitations and challenges.

A. Methods

1. ITS approach

We will use the same evaluation design we plan to use in measuring impacts on grid outcomes—an ITS design—to measure impacts on business and household outcomes. The ITS analysis will leverage multiple data points gathered from high-frequency mobile phone surveys before and after the implementation of the Electricity Generation and Distribution Projects to estimate impacts on short-term end-user outcomes. Gathering repeated observations from the same households and businesses will allow us to estimate trends in the outcomes before and after the interventions. We can then use those data to determine whether there was a clear change in the trends after project implementation. Our analysis will account for confounding factors that may affect end-user outcomes, such as day-of-week and seasonal effects. As with the analysis of grid-level outcomes, to account for seasonal effects (which may affect both household and business economic activity), we plan to collect at least one year[12] of pre-intervention information, and will include season-specific indicators in the regression analysis.

2. Pre-post approach with longitudinal data

A pre-post analysis will complement the ITS analysis by looking at how outcomes change for households, as well as small businesses over time. Although a pre-post analysis cannot establish causality, it will provide information on longer-term outcomes and thus complement

[11] We will measure firm size based on the number of employees. We will use the firm size delineations from the World Bank Enterprise Survey: small businesses have 5 to 19 employees, medium businesses have 20 to 99 employees, and large businesses have 100 or more employees.

[12] The actual start date for building the infrastructure investments may vary across regions and across types of investments. We plan to start data collection across all project areas at the same time and will aim to collect one year of pre-intervention data. The start date will be adjusted as Compact implementation plans evolve.

the impact analysis of short-term outcomes estimated using the ITS approach. Specifically, for the pre-post analysis of end-user outcomes, we will conduct three rounds of surveys: a baseline round (approximately one year before the intervention), an interim (medium-term) follow-up, and a final (long-term) follow-up. These three rounds will create a longitudinal panel of a sample of businesses and households, allowing us to apply a pre-post design that accounts for time-invariant characteristics of the businesses and households in our sample when measuring the changes in outcomes over time.

B. Outcomes and their anticipated time frame for realization

1. Short-term outcomes

The ITS design will estimate impacts of short-term decision making in response to changes in electricity quality and reliability by comparing outcomes before and after a project activity comes online. An ITS is appropriate for outcomes that would respond rapidly to improvements in electricity quality (such as generator use and hours of operation) but is not suitable for those outcomes that change gradually (such as expanded business production and productivity). Our proposed ITS design will measure the impacts on a small number of short-term outcomes for electrified businesses and households over the period of up to one year after the improvements are made.

For electrified small, medium, and large businesses, we will focus on measuring energy costs and weekly or monthly firm profits. The mobile phone survey for electrified households will focus on changing total energy use, time use, and energy expenditure in response to better power provision. Together, the impact analysis will address business and household outcomes in the following key domains: (1) outages; (2) satisfaction with SBEE; (3) total energy use; (4) operating hours; (5) profits, costs, and losses; (6) equipment failure; and (7) time use. The domains and illustrative outcomes for households and businesses we propose to measure are summarized in Table VI.1. We will work with MCC and stakeholders to finalize a short list of questions for the mobile phone survey.

Table VI.1. Proposed short-term end-user outcomes for ITS analysis

Outcome domain	Outcome measures	
	Businesses	Households
Outages	Frequency of outages Duration of outages	Frequency of outages Duration of outages
Satisfaction with SBEE	Satisfaction with power provision from SBEE Satisfaction with SBEE customer service	Satisfaction with power provision from SBEE Satisfaction with SBEE customer service
Energy use	Amount and cost of electricity consumed from the grid Amount and cost of electricity consumed from generators Possibly the amount and cost of energy consumed from some other energy sources	Amount and cost of electricity consumed from the grid Amount and cost of electricity consumed from generators Possibly the amount and cost of energy consumed from some other energy sources
Hours of operation	Weekly hours business is open	N/A

Outcome domain	Outcome measures	
	Businesses	Households
Profits, costs, and losses	Weekly or monthly profits (depending on size of firm) Cost of spoilage (destruction of raw materials) Revenue lost from stopped production (lost output) Cost of restarting production	Cost of spoilage (destruction of raw materials)
Equipment	Occurrence of equipment/appliance failure Cost of replacing or repairing defective equipment/appliances	N/A
Time use	N/A	Hours worked Hours of study (for one child in the household)

2. Longer-term outcomes

The pre-post analysis will focus on outcomes that take longer to materialize, such as fixed capital investments, growth, productivity, and income (for businesses), and connection decisions and education outcomes (for households). Over the nine-year evaluation period, we will conduct longer, face-to-face surveys with electrified households and businesses to measure these longer-term outcomes. The baseline data collection will occur before the start of project activities. The baseline period is critical for the pre-post analysis: it provides the point of comparison from which to measure changes in the outcomes over time. The interim data collection will occur one to three years after the intervention, a period that should be sufficient to detect changes in most outcomes, including grid and non-grid electricity consumption, adult and child time use, business profitability, and equipment expenditures. At the final data collection, which will occur two years after the interim data collection, or approximately three to five years after the intervention, we will be able to detect changes in these outcomes for beneficiaries in communities that received the intervention near the end of the compact. The timing of the interim and final data collections and the time span between each survey round may be adjusted if investments are not completed until the end of the compact. We will also be able to observe whether the changes documented at the interim data collection have been sustained. Overall, the three rounds of surveys will form a panel of (1) small, medium, and large businesses; and (2) households, and provide data on a broad range of outcomes.

We will conduct the **business surveys** with owners of electrified small formal and informal businesses (drawn from the household listing) and include detailed information on how improvements to electricity reliability and quality led to changes in productivity and investment. Changes in investment can occur through reduced reliance on self-generated power, changes to the firm's input mix, and investments stemming from reassurance that reliable grid electricity is available. We propose to measure changes in the following long-term firm characteristics: (1) profitability, (2) input mix (including number of employees) and capital investment, (3) costs of grid and non-grid electricity, (4) ratio of electricity costs to total costs, (5) ratio of electricity costs to revenues, (6) spending on equipment (for example, generators and surge protectors) to mitigate issues regarding unreliable power, (7) spending on equipment damaged due to poor-quality electricity, and (8) long-term expectations of reliability and quality of electricity supply.

We will conduct the **household surveys** with household heads and examine how electrified households have responded to improved electricity provisions across several domains. These responses include (1) the decision to connect to the grid; (2) grid and non-grid electricity consumption and expenditures, and consumption of non-electric energy; (3) perceptions of the reliability and quality of electricity; (4) investment in and ownership of generators, protective equipment, and electric appliances; (5) adult time use; and (6) child time use (including studying at night and watching television).

C. Analysis plan and statistical power

1. ITS analysis

We will conduct analyses separately for households and businesses because we expect them to benefit from the project activities in very different ways. In implementing the ITS analysis for estimating impacts of the Electricity Generation and Distribution Projects on short-term business and household outcomes, we will follow an estimation strategy similar to the one we described for estimating impacts on grid-level outcomes (see Chapter V). We will try to account for other confounding factors, as well as for baseline characteristics specific to transformers and catchment areas, and for seasonality of outcomes.

a. ITS power calculations

The use of mobile phone surveys will allow us to collect data from a large sample of businesses and households at a relatively low cost. Obtaining a large sample size ensures that we will have sufficient power to detect meaningful household and business impacts. In Table VI.2, we present the MDI for the end-user outcomes separately for medium and large businesses, small businesses, and households. For each group of beneficiaries, we present MDIs for different sample sizes that reflect the number of beneficiaries benefiting from individual and groups of project activities.

Medium and large firms. With a sample of 400 medium and large electrified firms, we would be able to detect an increase in profits of about 8 percent due to project activities. We think it likely that we would be able to detect this level of impacts because we would sample from energy-intensive firms and those that would benefit from a medium voltage connection. The MDI for a sample of 40 firms—which would be the sample size for project activities that affect only a small number of beneficiaries—is 24 percent of baseline profits. This percentage is too large to be realistic and suggests that we would not be able to estimate disaggregated impacts.

Small firms. With a sample of 750 small electrified firms, drawn from the household listing, we would be able to detect increases in firm profits of 6 percent of profits for the entire sample. This finding corresponds to the case in which we assess the impact of distribution activity completion on firms because all firms will benefit from the improvements in distribution. The MDI for a sample size of 150—corresponding to the sample size per geographic area—would be about 13 percent. Because we plan to oversample energy-intensive firms (as discussed in Section D), it is possible that we would see an increase in profits of 13 percent as they shift their energy source to grid electricity and experience fewer outages. It is unlikely that we would be able to assess impacts for smaller subgroups—for example for specific project types—for which we assume a sample size of 50 firms, as the MDIs are too large to be achieved reasonably by improvements in electricity generation, reliability, and quality.

Households. With a sample of 1,500 electrified households, we would be able to detect an increase in consumption of electricity of about 4 percent for the overall sample and increases of about 4 percent in the time children study in the evening. With a sample of 300 households—which would correspond roughly to the sample size per project area—we would be able to detect increases in electricity consumption of about 8 percent and 9 percent for children's evening study. We think that these effects are plausible, given MCC's large investments in the electricity sector. We would also sample at least 300 female-headed households (as discussed in Section D), to be able to disaggregate the results by gender of the household head. The MDI for subgroup analyses for female-headed households is 8 percent and 9 percent, respectively, for electricity consumption and children's evening study. These are relatively large MDIs and are likely to occur only for very specific subgroups, such as households in areas in which faulty transformers were replaced by the project or in which outages were very frequent before MCC's project investments.

Table VI.2. Minimum detectable impacts for ITS analysis

Analysis unit/ beneficiaries	Evaluation design	Sample size	Outcome	Baseline mean	MDI	MDI (% change from mean)
Medium and large businesses	ITS	400	Monthly profit (USD)	94.5	7.3	7.7%
Medium and large businesses	ITS	40	Monthly profit (USD)	94.5	23.0	24.3%
Small businesses	ITS	750	Monthly profit (USD)	94.5	5.3	5.6%
Small businesses	ITS	150	Monthly profit (USD)	94.5	11.9	12.6%
Small businesses	ITS	50	Monthly profit (USD)	94.5	20.6	21.8%
Households	ITS	1,500	Total energy consumption (kilowatt hour [kWh])	827.6	30.2	3.7%
Households	ITS	300	Total energy consumption (kWh)	827.6	67.6	8.2%
Households	ITS	100	Total energy consumption (kWh)	827.6	117.0	14.1%
Households	ITS	1,500	Child night study (hrs)	0.6	0.02	3.9%
Households	ITS	300	Child night study (hrs)	0.6	0.05	8.6%
Households	ITS	100	Child night study (hrs)	0.6	0.09	14.9%

Notes: We assumed a confidence level of 95 percent, two-tailed tests, 80 percent power, 25 percent sample attrition for surveys, an R-squared of 0.3 and an autocorrelation of 0.35. Information on mean and standard deviations are from the World Bank (2009) enterprise survey for Benin, the World Bank Entreprenant Evaluation (Benhassine et al. 2015) and World Development Indicators (World Bank 2016). Correlation across time were computed from data for the Tanzania energy evaluation (Chaplin et al. 2017). The standard deviations are 94.25 for monthly profit, 758.7 for energy consumption and 0.6 for the number of hours children study at night.

2. Pre-post analysis with longitudinal data

We will estimate changes in key outcomes over time separately for electrified households and businesses, in the same way we did for the ITS analysis. We will follow an estimation strategy similar to the one described in Chapter V for the pre-post analysis of grid-level outcomes and will measure follow-up outcomes at the time of the interim and final data collection rounds.

Although our primary analysis will be based on the responses of all household heads or business owners for which the outcome is available, we will also conduct subgroup analyses to inform the research question related to differences in changes over time by business type and sector (RQ9) and poverty or gender (RQ10). The business subgroups are defined by the following baseline characteristics: (1) location of premises, (2) formality of the business, (3) sector, and (4) gender of the business owner or manager. For households, we will apply the regression model to household subgroups as defined by the following baseline characteristics: (1) vulnerable or poor households and (2) gender of the household head. We are also interested in how changes in the measured outcomes may vary depending on the baseline connection status of households and businesses. To explore these differences, we will also conduct subgroup analyses for connected and non-connected households.

Findings from the pre-post analysis should not be interpreted as project impacts because time-varying factors unrelated to the project could still be driving some of the observed changes. Specifically, we cannot account for other interventions that may affect the quality and reliability of electricity in the project areas or that may affect household and business outcomes directly. Therefore, without a valid counterfactual, the estimated changes cannot be fully attributed to the project. Nevertheless, this approach will provide suggestive evidence of the longer-term changes possible for households and businesses when better-quality and more reliable electricity is available. With two different data points after the implementation of activities, it will also provide some evidence on how long it takes benefits to materialize, and whether any benefits observed at the interim data collection are sustained two years after the end of compact—that is, at the time of the final data collection.

D. Data sources

The ITS analysis will rely on data from high-frequency (quarterly) mobile phone surveys, whereas the longitudinal pre-post analysis will use data from the three rounds of face-to-face surveys. We will conduct a quarterly mobile survey of businesses and households, allowing us to obtain data on a select list of short-term outcomes for businesses and households. To capture longer-term outcomes, we will also conduct a set of face-to-face business and household surveys in three rounds: baseline, interim, and final. Table VI.3 below shows the various data sources for the quantitative analysis of end-user outcomes.

Table VI.3. Quantitative sampling and data collection

Data sources	Sample size	Timing	Relevant instruments/ modules
ITS analysis (short-term outcomes)			
Mobile phone survey of male and female business owners/managers	1,150 electrified businesses (750 small and 400 medium and large businesses)	Quarterly surveys between baseline and interim data collections for the pre-post survey (and perhaps beyond)	• Outages • Satisfaction with SBEE • Energy use • Operating hours • Costs and losses • Equipment
Mobile phone survey of male and female household heads	1,500 electrified households	Quarterly surveys between baseline and interim data collections for the pre-post survey	• Outages • Satisfaction with SBEE • Energy use • Costs and losses • Equipment • Time use
Pre-post analysis (medium and long-term outcomes)			
Pre-post survey of male and female business owners/managers	300 small businesses	• Baseline (pre-intervention) • Interim (2–3 years of exposure) • Final (3–5 years of exposure)	• Profitability • Input mix and capital investment • Energy costs • Spending on equipment to address unreliable power • Spending on equipment damaged due to poor-quality electricity • Expectations of reliability and quality of electricity supply
Pre-post survey with male and female household heads	300 households	• Baseline (pre-intervention) • Interim (2–3 years of exposure) • Final (3–5 years of exposure)	• Grid and non-grid electricity and substitute energy consumption • Reliability and quality of electricity • Operation of businesses outside of the home • Adult time use • Child time use

Notes: Very precise estimates are not necessary for the pre-post analysis of medium and long-term outcomes, allowing us to draw a smaller sample for the face-to-face surveys.

To conduct the ITS analysis, we will link the quarterly mobile phone survey data from businesses and households with information on the timing of improvements to the distribution network and introduction of new generation capacity, and from grid monitors installed on the grid that will provide real-time data. Matching our mobile phone survey data with grid-monitor data will allow us to measure the effect of the interventions on the short-term choices and outcomes among businesses and households. Smart meters will be placed on the premises of households and businesses selected for our mobile phone and face-to-face surveys.

Grid improvements may roll out at different times in the different project areas, and some may occur earlier than others within the same project area. For this reason, Mathematica will start administering the mobile phone surveys as soon as possible after the compact entry into force to ensure that we have adequate pre-intervention data in all project areas. The mobile phone surveys will be conducted on a rolling basis until, and possibly beyond, the interim data collection near the end of the compact.

We will schedule the high-frequency interviews with end users to be collected quarterly. As a result, we will make observations before and after the introduction of project activities, which can come online at any point. Our ability to detect impacts for specific projects may still be limited when project activities affect small numbers of end users and the time gap between project activities is brief. (See the MDI calculations above.) As we aggregate the estimation by type of activity, our power to detect impacts will rise.

We will obtain the data necessary for the pre-post analysis of longer-term outcomes for businesses and households by conducting three rounds of data collection: baseline (before the implementation of activities), interim (near the end of the compact), and final (two years after the conclusion of the compact). We will complement the business and household surveys with qualitative data captured through in-depth interviews with business owners and focus group discussions with household members (see Chapter VII).

Below we discuss the sampling for both surveys and then describe the data collection plan separately for each type of survey.

1. Sampling

The basis of our sampling strategy for both the ITS and pre-post analysis of household and small business outcomes will be a household listing. We will sample households and businesses located in the distribution areas of the transformers selected for the analysis of grid-level outcomes (outlined in the grid-monitoring section above).[13] The data collection team will then conduct a listing exercise for all households living in the area, or a randomly selected pre-specified portion of the transformer area if the costs of a complete listing are prohibitive. The data collectors will visit each household in the area and collect information from the household head or another available adult regarding the household contact details (including mobile phone number), household composition, geospatial positioning system (GPS) location, grid connection status, business ownership (inside or outside of the house, size, sector), employment, and ownership or rental of housing.[14] Once the listing is complete, we will select a stratified random sample of 750 small businesses and 1,500 households. We will stratify our household sample by electricity source (primary connection to the grid, secondary connection to the grid, access to electricity via generator) and gender of the household head. Our business sample will be stratified by industry to allow for oversampling of businesses in energy-intensive industries, such as garment manufacturing, cosmetology, welding, carpentry and masonry, cold stores, grinding mills, and automated cement mixers. The business sample will also be stratified by business size, whether it is inside or outside of the home, and gender of the owner. We will conduct a baseline face-to-face survey with these 750 small businesses and 1,500 households. Following the

[13] We will select households and small businesses from transformer distribution areas even if we do not have grid monitors because this strategy will allow us to tightly focus on areas that receive specific grid improvements. If it is infeasible to select them based on transformer catchment areas, we will instead sample them using census enumeration areas.

[14] We may also collect information on proxies for socioeconomic status, such as counts of certain assets (such as a bicycle, motorcycle, or car), toilet facilities, source of water, connection to water/sewage, floor space per person or number of people per room, number of meals per day, and/or data necessary to calculate the Grameen Bank's *Progress out of Poverty Index (PPI)*. These data would provide a finer measure of socioeconomic status, but we will need to balance the cost of listing with the value of the additional information.

baseline survey, we will collect quarterly mobile phone surveys with these same businesses and households. For the pre-post analysis, we will conduct the interim and final face-to-face surveys with a subsample of 300 households and 300 businesses from the ITS sample. Very precise estimates are not necessary for the pre-post analysis, allowing us to draw a smaller sample for the face-to-face surveys.

To define our ITS sample frame for medium and large businesses, we will collect data from SBEE, the Chamber of Commerce, and l'Institut National de la Statistique et de l'Analyse Economique (INSAE) to develop a list of commercial customers connected to the electricity grid in the transformer areas. We will stratify by project area, recognizing, for example, that more industry exists in Cotonou and Parakou and there may be relatively few customers with medium-voltage connections in Natitingou, Djougou, or Bohicon. We will also stratify by industry type, ensuring that key industries and any existing energy-intensive industries are represented by oversampling those groups. In total, we plan to sample 400 medium and large businesses across all project areas.

2. Data collection approach

a. ITS quarterly mobile phone surveys

For the quarterly mobile phone surveys, Mathematica will design surveys on a computer-assisted personal interviewing (CAPI) platform that a local data collection firm will administer to households and businesses via mobile phone. Mathematica will employ a number of best practices to ensure that these surveys result in high quality and consistent data over the life of the evaluation. For instance, Mathematica will pilot the survey instrument with a variety of different businesses to ensure that the questions are relevant and easily answered. When needed, the survey will be administered in a local language. Mathematica will provide respondents with information on the types of questions we will ask during the face-to-face survey before the first mobile phone survey. This approach will allow respondents to reflect on and gather the information necessary to complete the survey. In the subsequent rounds, Mathematica will send text message reminders in advance of the survey, such as "Please keep track of any power outages this week" or "Please record your electricity spending during this week." We will also be able to conduct validity checks by contrasting the information received during a mobile phone survey with information provided by the same respondent during the baseline survey and all previous mobile phone surveys. This approach will allow surveyors to identify any out-of-range or inconsistent responses that may require additional follow-up. Data collectors will enter responses directly into a computer, the data will be uploaded daily to a secure server, and Mathematica will conduct frequent consistency checks to quickly identify any discrepancies. Finally, data collection supervisors will be required to conduct call backs with 10 to 15 percent of respondents in each round to verify responses.

b. Pre-post business and household surveys

Mathematica will design surveys that a local data collection firm will translate into relevant local languages and administer to households and small businesses in three rounds of data collection: baseline, interim, and final. To improve data quality, we will require that the firm use the CAPI program Survey Solutions. Using CAPI will integrate the data collection and data-entry steps and minimize the opportunities for error. For example, we can build validity checks into the questionnaires that will prevent the survey from advancing if an out-of-range response is entered. Mathematica will ensure that the enumerators are properly trained in the use of CAPI, the instruments are pre-tested and piloted, and the data collection firm's field oversight protocols meet Mathematica's standards. For instance, we will require that supervisors revisit 10 to 15 percent of interviewed households and businesses to verify that the survey was conducted and confirm some of the results. Data will be uploaded daily, and Mathematica will conduct frequent consistency checks to quickly identify any data collection problems. Data transfer and security procedures are discussed in Chapter VIII.

The data collectors will visit each community once during each data collection round to conduct the listing (baseline only) and the face-to-face household and business surveys. Our data collection team will include a local research coordinator who will help to organize and monitor on-the-ground operations through regular feedback meetings and unannounced site visits; the coordinator will also ensure that all data are collected according to the highest standard of quality. The local research coordinator will oversee piloting of the survey instruments, and staff from Mathematica will travel to Benin to oversee the training of data collectors. We will work with MCC to identify a qualified data collection firm. Ideally, this firm will have the following desired qualifications: experience with CAPI, large-scale surveys, and surveys of households and businesses in urban areas; country expertise; an existing pool of qualified enumerators who, combined, speak a range of local languages; and the ability to bring together a strong team of supervisors. If MCA-Benin is responsible for hiring the data collection firm, Mathematica will assist with drafting the scope of work and be available to review applications. To ensure high quality of data, Mathematica would recommend formalizing its role in reviewing any final data set and providing a formal recommendation of acceptance for the contract between MCA-Benin and the data-collection firm.

E. Challenges

1. **Disaggregation of impacts by project activity.** Contrary to the large number of grid-level measurements per year and day, we will observe households and small businesses only up to four times a year. It is possible that two (or more) project activities will come online within a short time of each other, so there will not be sufficient time to precisely measure the outcome changes after the first project activity or establish sufficient observation points before the second intervention to assess the ITS assumptions. In this case, we would be able to assess only the impacts of the bundle of the two (or more) interventions.

2. **Lack of mobile phone ownership will exclude some respondents from the mobile phone survey.** Given this constraint, the findings of our research will only apply to the subset of electrified households and small businesses with a mobile phone. While we do not have data on mobile phone ownership for our specific populations of interest, data from other studies suggest that mobile phone ownership among households in Africa has risen dramatically in recent years and is likely to be high in Benin (Pew Research Center 2015). Benin's ownership rate is likely to be similar to that of other countries in the region for which data is available, such as Nigeria (87 percent), Senegal (84 percent), and Ghana (83 percent) (Pew Research Center 2015). These percentages, from 2014, have almost certainly risen since then. As mobile phone ownership is typically higher in urban areas where access to mobile phone service is higher (Afrobarometer 2016), it is likely that only a small minority of households and small business owners in urban areas of Benin do not own a mobile phone. Moreover, mobile phone ownership is likely to be even higher among households and small

business owners with a grid connection. However, if we do find that a large percentage of households or small business owners do not own a phone, we will test whether we can administer the mobile phone survey to a respondent by calling a neighbor's phone. If this approach is not feasible, we will exclude respondents without a mobile phone from the survey and note this as a limitation to the research.

3. **Low response rates and attrition from the mobile phone survey.** The mobile phone survey will require numerous contacts with the same respondent over a period of a few years. For this reason, response rates may be low, and overall attrition may be high as the evaluation progresses. Attrition and low response rates can lead to underpowered and biased impact estimates. Mathematica will work with MCC and the data collection firm to determine the best methods of minimizing mobile phone survey attrition. It may be appropriate to offer a small incentive for responding to the survey—for example, by transferring mobile phone credits to mobile phone survey responders as compensation for their time (Dillon 2010). Also, the data collectors can calibrate the preferred time of contact for each respondent, attempt to call back three times, and record multiple phone numbers for reaching an individual. For large firms, we may request a list of multiple people in the company who could answer the survey questions. Finally, if we cannot reach a respondent via phone, we propose to attempt to interview the individual in person. Despite these strategies, some attrition will be likely over time. Mathematica will not replace missing respondents but will continue to attempt contact in each data collection round unless the respondent refuses. We will consider statistical approaches to account for attrition if it becomes a significant problem.

4. **Attrition of both businesses and households from our pre-post study sample** could also be a challenge, given that the data collection rounds will occur several years apart. Specifically, small businesses may be more likely to open and close during the study period. At baseline, households and businesses selected for inclusion in the pre-post sample that are absent or refuse to take the survey will be replaced with other eligible households and businesses. Mathematica will attempt to conduct surveys of respondents in the same location during each data collection round. That is, if a household moves out of the community after the baseline data collection, we will interview the new household living in the initially selected dwelling at the interim and final data collection rounds. We will not follow households that have relocated. Similarly, we will interview businesses operating out of the same location in each data collection round.

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VII. QUALITATIVE ANALYSIS

We will complement the quantitative impact and performance evaluations with a qualitative performance evaluation that includes two components. The first component is an implementation analysis of the Electricity Generation and Distribution Projects, which will provide valuable insights into research questions about the processes, activities, and overall operations of the compact projects. The second component is a qualitative assessment of the effects of the project on improvements in electricity quality and reliability for connected households, businesses, and public institutions, as well as gaining access to electricity for newly connected households and small household-based businesses. In Section A of this chapter, we describe the methodology of both evaluation components. In Section B, we discuss the timing of each data collection round; in Section C, we summarize the sampling strategy. In Section D, we describe our data collection approach, in Section E we review our analysis plan, and in Section F we discuss limitations to the interpretation and the design.

A. Methodology

1. Implementation analysis

The implementation analysis will rely on a document review, infrastructure observation, and interviews to address research questions related to project implementation (RQ1), sustainability of the outcomes achieved (RQ2), the influence of outside factors on project objectives (RQ3), and lessons learned (RQ5). We will conduct a document review to synthesize reports and data from the Electricity Generation and Distribution Projects, SBEE, and other organizations. As an essential first step, we will use the theory of change and key implementation indicators to guide the document review and help us classify our findings into different themes. The documents we will review include the compact, the investment memo, the implementers' scope of work, annual reports, the compact completion report, implementer reports, and monitoring data. We expect that the reports and materials will record project timelines, achievements, challenges, modifications, and key lessons learned. The review will provide context and inform our other evaluation activities.

We will conduct observations of the distribution and generation infrastructure by using an observation checklist and questionnaire for stakeholders in charge of implementation or maintenance, depending on the stage of implementation. We will also conduct interviews with selected stakeholders. These interviews will provide a confidential setting to explore respondents' personal perspectives and highlight challenges that the implementers faced. We will interview key informants from MCA-B, MCC, the implementers, SBEE, community leaders, and other relevant stakeholders to obtain in-depth and detailed information on project activities. In addition, our local research coordinator will carry out routine check-ins with local stakeholders, including the Energy Sector Donor Roundtable participants. Interviews with these donors will also allow us to learn about additional activities in the electricity sector that might hinder or amplify the impact of MCC investments and that we must consider to provide impact estimates of MCC's project investments. We will conduct all interviews by asking questions and probing based on the informants' perspectives, knowledge, and experiences.

2. Qualitative assessment

For the qualitative assessment, we will conduct interviews with business owners or managers, and staff from public institutions, as well as FGDs with members of beneficiary households. During the interviews with business owners and managers, we will explore respondents' problems stemming from unreliable and low quality electricity, and their unique choices and experiences upon gaining access to improved electricity. We will also examine similarities and differences between business owners based on their business type. Given that owners are often unable to leave their work place or have time to join a group discussion, we will conduct these interviews at the respondents' place of business to increase the response rate (Miller et al. 2015). The qualitative outcomes analysis with business owners will answer research questions related to the impacts of the project activities on business outcomes (RQ9) and the impacts of new connections on small business outcomes (RQ12).

Next, we will conduct FGDs with a sample of household members connected to grid electricity. We will oversample households with household businesses to understand impacts on small businesses. A group discussion format allows us to obtain the perspectives of many more respondents than through interviews alone. We will stimulate conversation between participants in an interactive discussion to efficiently explore many perspectives and experiences. The FGDs with household members will explore research questions related to the impact of the project on household outcomes (RQ10) and the impacts of new connections on household outcomes (RQ12). The FGDs will enhance our understanding of behaviors and perceptions not easily measured in a survey, such as the constraints households face due to low quality electricity, their strategies for dealing with outages, and the extent to which they have noticed improvements in quality. This information will not only improve our understanding of the impacts of the Electricity Generation and Distribution Projects, but may also influence the questions included in our survey instruments. We will also conduct interviews with staff from public institutions at their place of work to understand how outcomes for public and social services have changed as a result of the projects (RQ11).

B. Time frame of exposure

The proposed qualitative performance evaluation will involve three rounds of qualitative data collection that will coincide with the main rounds of the quantitative data collection. These activities will occur at baseline (about one year before the start of implementation), during interim data collection (near the end of the compact period, or approximately one to three years after the start of project activities), and during final data collection (approximately two years after compact completion, or three to five years after the anticipated start of project activities). The interim data collection will occur sufficiently close to the end of the compact to reflect on the full implementation of project activities and document early changes in beneficiary outcomes and perceptions. The two years between the interim and the final data collection rounds will allow enough time for patterns in maintenance practices to be observed and longer-term beneficiary decisions and outcomes to emerge.

Each round of data collection will contribute timely and unique information to the overall understanding of the effects of the Electricity Generation and Distribution Projects. For the **baseline data collection**, our focus will be on understanding the final project design and the pre-compact status quo. Specifically, our interviews with implementers and other stakeholders will focus on design details, expectations for implementation, and pre-implementation perceptions of the constraints and challenges in the Benin energy sector. The FGDs and interviews with households and businesses will gauge the pre-compact situation and perceptions of beneficiaries, such as their total energy use, interactions with SBEE, the quality and reliability of their electricity, and the challenges they face related to energy use. The information we obtain from these sources may also help us refine topics for the quantitative data collection if we gather qualitative data before the quantitative data collection.

During the **interim data collection**, which will occur near the end of the compact, we will concentrate on the actual implementation of the Electricity Generation and Distribution Projects, and on stakeholders' perceptions of grid improvements. Our electrical engineer will conduct observations of the completed infrastructure by using an observation checklist and questionnaire. Interviews with MCA-Benin and SBEE staff and the project engineers will focus on the implementation of each project's activities, any issues faced during implementation, any new constraints or challenges encountered over the life of the compact, and overall lessons learned. The FGDs and interviews with households and businesses will explore the early experiences of beneficiaries related to the same topics covered at baseline, such as interactions with SBEE, updates on total energy use, energy and equipment expenditures, and electricity quality and reliability. We will also seek to understand any constraints end users face that may prevent them from fully benefiting from additional generation and grid improvements. Because this round of data collection will occur near the end of the compact, we expect the data gathered will provide information on the full implementation of all activities.

Finally, during the final data collection, we will focus on sustainability and perceived benefits two years after the compact's end. The observations and related questionnaire will focus on maintenance of the new infrastructure. Interviews will cover topics such as reflections of SBEE staff and community leaders on the implementation of the compact activities, challenges and successes, and expectations for sustainability. FGDs will explore whether and to what extent households and businesses perceive improvements in the beneficiary outcomes laid out in the theory of change.

C. Study sample

We propose to select our respondents for interviews and focus groups as follows:

Interviews with MCA-Benin staff, SBEE management, SBEE line workers and customer service representatives, and implementers. During each round of data collection, we will interview respondents with a deep knowledge of the Electricity Generation and Distribution Projects. During the baseline and interim data collections, we plan to interview MCA-Benin staff in the contracting, energy, and M&E divisions, and engineers and contractors from the implementer who can provide detailed information on project design, implementation, and challenges and successes. During all three rounds of data collection, we will interview SBEE staff working with MCA-Benin on compact activities and those working on the lines and with customers in the project areas to understand implementation challenges and successes and maintenance processes. We will work with MCA-Benin and SBEE to develop a complete list of relevant staff, contractors, and partners to interview, aiming for representation across project areas.

Interviews with community leaders, staff from public and social services, and owners and managers of businesses. For the qualitative data collection, we will select four to six communities to ensure representation from the different project areas and include perspectives from communities that differ based on socioeconomic status and urban/rural status. We will select one urban and one rural community from the northern project areas (Djougou, Natitingou, and Parakou), and urban communities in Cotonou, Porto Novo, and Bohicon from the southern project areas, where project activities will be concentrated in urban areas. Within the selected communities, we will try to have the data collection team conduct interviews during the same visit in which they administer the quantitative surveys. First, the team will identify and interview the community leaders, local officials, and neighborhood energy associations who have worked with SBEE to determine the placement of lines and other compact investments. Next, the team will interview the community's school headmaster and health facility director. In addition, we will select 6 business owners or managers to interview per project area, with the exception of Cotonou, where we will aim to interview 12 owners and managers. These businesses will be purposively selected from among electrified businesses in the business listing developed for the quantitative survey during the first community visit to ensure representation across size and industry. We will attempt to interview the same respondents again during the interim and final data collections. If some managers have left the business, we will attempt to interview their successors. If respondents refuse or are unavailable, we will replace them with an owner or manager of the same type of firm.

Focus groups with households. We will conduct FGDs with electrified households in the same four to six communities in which we will conduct interviews with businesses. The data collection team will purposively select households to ensure a wide representation in socioeconomic status and household characteristics across the different focus groups. To make sure all respondents feel comfortable expressing their opinions, we will rely on our data collection team and local research coordinators' cultural knowledge to assign respondents to groups homogenous enough to encourage open discussion. We will invite one member from selected households (the primary male or female adult) to participate in the focus group. We will conduct separate focus groups for men and women; each group will comprise 6 to 12 participants. An FGD of this size is large enough to ensure that we obtain a variety of perspectives but small enough for each person to have an opportunity to share opinions. If some selected household members are unavailable or refuse to participate, we will select additional participants to reach a group of adequate size.

Observations of infrastructure. We will conduct structured observations of the built and rehabilitated infrastructure, and carry out related interviews of implementation or maintenance engineers in select sites along the distribution and generation networks. We will determine the specific locations and number of discrete observations based on the final implementation plan and on information gathered through ongoing document review and stakeholder conversations in the early years of implementation.

Finally, if we carry out the proposed connection study and impact evaluation of discounted price connections with residents in Cotonou (see Appendix A), we will hold FGDs in the areas receiving the discounted connections and tariffs. We would select households that are potential beneficiaries, aiming for a range of socioeconomic status and with both genders represented. In each project area, we will attempt to bring together the same group of respondents for the interim and final data collections. If participants are unavailable because they have moved, we will invite a member of the household that has moved into the original participants' lodging. If participants are unavailable for other reasons, we will select a replacement with similar characteristics.

D. Approach to data collection

We will implement the following approach to data collection for the evaluation. For the document review, Mathematica will work with MCC and MCA-Benin to develop a list of documents to review at each data collection round. Our local research coordinator will assist in collecting the documents. Mathematica will work with the design consultant to monitor SBEE's maintenance plan and review reports from SBEE. For the interviews and FGDs, we will develop semi-structured instruments and guides, respectively, for each group of respondents to ensure that we explore the key areas of focus during each round of data collection (as elaborated in Table VIII.1). The semi-structured instruments for key informant interviews will allow us to gather targeted information to understand project implementation and outcomes while permitting an expanded conversation that can lead to unanticipated insights. The FGD guides will allow us to facilitate an open discussion on both the benefits and drawbacks of the changes in households and communities resulting from new connections.

In Table VII.1, we summarize how we propose to address the areas of focus across the data collection rounds, by data source. However, before conducting the study, we will ask MCC, MCA-B, and SBEE for feedback on the participant list and areas of focus to ensure that we have a comprehensive yet parsimonious plan that enables us to assemble the full picture of implementation and outcomes. Table VII.1 also includes the sample size and data type for each data source. The planned sampling strategy for each activity is discussed in the following section.

Table VII.1. Key areas of focus for qualitative data collection, by respondent

Data source	Sample size and data type	Key areas of focus: Baseline (before project implementation)	Interim (near the end of compact; 1–3 years of exposure)	Final (2 years post-compact; 3–5 years of exposure)
MCA-Benin representatives in the energy, contracting, and M&E departments; MCC Resident Country Mission staff; National Coordinator; GSI and ESP experts; and other relevant staff	4–8 interviews per round	*Design details* • Changes to the initial project design • Perceptions of the design of compact investments *Pre-compact status quo* • Perceptions of electricity reliability and quality, maintenance • Constraints and challenges	*Implementation and sustainability* • Planning and execution of contracts • Coordination between organizations • Communication across regions and communities • Implementation successes and challenges • Impact of outside factors • Possible challenges to sustainability	*Sustainability* • Sustainability of grid enhancements • Challenges to sustainability • SBEE adherence to maintenance plans Full MCA-Benin will no longer exist
SBEE policy, management, and engineering staff; staff at Ministry of Electricity and regulatory bodies	8–10 interviews per round	*Design details and expectations for implementation* • Anticipated challenges to implementation • SBEE's role in the design and implementation of infrastructure interventions *Pre-compact status quo* • Perceptions of electricity reliability and quality, maintenance • Constraints and challenges	*Implementation* • Implementation plans and design changes • Implementation successes and challenges • Placement of lines • Perceptions of the quality of materials and work • Maintenance plans	*Sustainability* • Sustainability of grid enhancements • Challenges to sustainability • Adherence to maintenance plans
SBEE line workers and customer service	4–6 interviews per round	*Expectations for implementation* • Anticipated challenges to implementation	*Implementation* • Placement of rural lines • Perceptions of the quality of materials and work • Response time successes and challenges	*Sustainability* • Sustainability of grid enhancements • Challenges to sustainability • Adherence to maintenance plans
Engineers and contractors from the implementing organizations responsible for design and construction of the infrastructure, and project deliverables.	4–6 interviews per round	*Design details* • Anticipated changes to the project design • Anticipated challenges to implementation	*Implementation* • Comparison of planned activities and actual implementation • Reasons for deviations from planned activities • Challenges and successes	*Not applicable* Staff from the implementing agencies will likely no longer be available.
Local community leaders, local officials, and/or representatives from energy associations who	8–12 interviews per round	*Pre-compact activities status quo and perceptions* • Satisfaction with quality and reliability of grid electricity	*Implementation status* • Satisfaction with grid design and implementation	*Sustainability* • Satisfaction with grid design and implementation

Data source	Sample size and data type	Key areas of focus Baseline (before project implementation)	Interim (near the end of compact; 1–3 years of exposure)	Final (2 years post-compact; 3–5 years of exposure)
interact with SBEE and implementers		• Consequences of lack of reliable and high quality electricity	• Perceptions of communication and coordination	• Strengths and weaknesses of approach
Male and female owners, managers, and representatives of small, medium, and large electrified businesses	12–15 interviews per round	*Pre-compact activities status quo and perceptions* • Energy use and expenditure • Expectations for benefits of improved electricity • Equipment damage and losses due to power outages and surges • Consequences of lack of reliable and high quality electricity	*Early experiences of beneficiaries* • Energy use and expenditure • Perceived benefits of improved electricity • Equipment damage and losses due to power outages and surges	*Perceived benefits* • Energy use and expenditure • Perceived benefits of improved electricity • Equipment damage and losses due to power outages and surges
Primary male and female members of electrified households	8–12 FGDs per round Sample for optional impact evaluation (the connection study): 6 FGDs per round	*Pre-compact activities status quo and perceptions* • Energy use and expenditure • Expectations for benefits of improved electricity • Adult and child time use • Satisfaction with electric utility • Consequences of lack of reliable and high quality electricity • Optional connection study: constraints to connecting	*Early experiences of beneficiaries* • Energy use and expenditure • Perceived benefits of improved electricity • Adult and child time use • Satisfaction with electric utility • Optional connection study: constraints to and benefits of connecting	*Perceived benefits* • Energy use and expenditure • Perceived benefits of improved electricity • Adult and child time use • Optional connection study: constraints to and benefits of connecting
Director and managers from schools, health clinics, and other public institutions	8–12 interviews per round	*Pre-compact activities status quo and perceptions* • Energy use and expenditure • Expectations for benefits of improved electricity • Equipment damage and losses due to power outages and surges • Consequences of lack of reliable and high quality electricity	*Early experiences of beneficiaries* Energy use and expenditure • Perceived benefits of improved electricity (for example, service hours and service quality) • Equipment damage and losses due to power outages and surges	*Perceived benefits* • Energy use and expenditure • Perceived benefits of improved electricity (for example, service hours and service quality) • Equipment damage and losses due to power outages and surges
Project implementation plans and progress reports	Document review	*Design details* • Project implementation plans	*Implementation summary* • Project implementation milestones and successes • Delays and challenges in project implementation • Revenue and expenditure data	*Implementation summary* • Post-compact monitoring reports (if available)

To ensure the collection of high quality qualitative data, Mathematica will work closely with MCC, MCA-B, and the implementing contractors and consultants to gather the necessary data and documents, identify key stakeholders and beneficiaries to interview, and finalize the timing of data collection. The Mathematica evaluation team will conduct key informant interviews in French when possible and will use a local data collection firm to conduct interviews and FGDs in local languages. We would prefer to use the same firm that conducts the quantitative data collection to increase efficiencies in interviewer training and travel, given that the quantitative data collection will occur at the same time. However, we will select the firm that can ensure the highest possible quality work and may need to work with separate firms for the quantitative and qualitative data collections. We will work with MCC and MCA-Benin to identify a data collection firm that has experience with qualitative data collection methods, such as conducting FGDs for social policy purposes. We would prefer the firm to have experience in using NVivo or similar qualitative analysis software. Ideally, this firm will be able to recruit, hire, and train researchers who are bilingual in French and another local language, and have experience in conducting high quality data collection. In addition, we would expect the firm to provide input on the protocol and instruments; screen and select individuals from households, businesses, and public institutions for focus groups and interviews; and provide word-for-word transcriptions of digital recordings of FGDs and key informant interviews.

Mathematica will develop the terms of reference and closely oversee all questionnaire development, testing, piloting, training, and fieldwork. Following fieldwork, the data collection firm will provide Mathematica with the original audio recordings of the interviews and FGDs and the transcripts. Mathematica will contract to have the transcripts translated into English. Mathematica's local research coordinator will also conduct a quality check of the original transcription and translation into French.

The qualitative team will participate in a data collection training session. The training will include a thorough review of data collection guides and processes, a description of sampling and recruiting procedures, a discussion and review of high quality transcripts from FGDs, mock and practice interviews/FGDs, and tool piloting and debriefing. We will closely monitor the entire data collection process with the assistance of a local research coordinator, who will help to organize and monitor on-the-ground operations, and ensure that Mathematica's data quality standards are met.

E. Analysis plan

Mathematica will obtain documents from a variety of sources, as described above in Section D. We will organize and categorize the documents according to their source and topic to understand how they relate to the Electricity Generation and Distribution Projects and the research questions. We will conduct a **content analysis** to identify themes, with a particular focus on issues related to the research questions, such as successes and challenges with project implementation, and sustainability of the electricity infrastructure. We will also document any ideas or issues that emerge from the review that should be explored further in the key informant interviews or FGDs.

Our analytic approach to analyzing the data collected through interviews and FGDs relies on thematic framing and triangulation and proceeds in four steps (Creswell 2009): (1) raw data review and management, (2) initial coding, (3) detailed coding and (4) data interpretation and writing. In the first step, we will read the English transcripts that the data collection and translation firms provide, and group the transcripts according to the data method and source (for instance, FGDs with male household heads or interviews with male owners of large businesses). During this step, we will **review all data** and eliminate any that are incomplete or not useful for our analysis.

In the second step, we will read through the transcripts several times to get a holistic sense of the data. We will further **develop the coding scheme—that is,** a set of themes we might encounter in the interview and focus group transcripts, mapped to the research questions and theory of change (for example, initial themes might include "implementation challenges," "lost productivity," and "equipment damage"). The third step involves **refining the coding scheme** and using NVivo or similar qualitative data analysis software to code the transcripts according to key themes. We will review, organize, and analyze the codes produced through this software into themes that relate to the theory of change and the evaluation questions, and that are present across multiple respondents. We will then 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 interviews, FGDs, and our other data sources, including household, business, and public service survey data, administrative and grid monitor data, and project documentation. This process will facilitate the identification of new trends and relationships, confirm patterns or findings, and detect discrepancies or disparate experiences. A coding hierarchy will guide the process of triangulating findings across data sources and types. For example, when investigating the project's impact on response time as related to technical problems on the grid, we will triangulate grid monitor data on outage durations, findings from interviews and focus groups on interactions with SBEE, and administrative data from SBEE on average response times.

F. Challenges

1. **Key benefits of the Electricity Generation and Distribution Projects may depend on the Policy Reform and Institutional Strengthening Project.** Some of the key benefits of the Electricity Generation and Distribution Projects may be realized and sustained only if the Policy Reform and Institutional Strengthening Project is implemented completely and according to the expected timeline. Thus, even though the reform activities are outside the scope of this evaluation, we will rely on documentation and evaluation reports from them to fully understand the factors influencing the effectiveness of the Electricity Generation and Distribution Projects. If these documents are not available at the time of our interim and final data collections, we will not be able to assess this influencing factor. We have already had several conversations with MCC staff about the important linkages between the Policy Reform and Institutional Strengthening Project and the Electricity Generation and Distribution Projects. We will continue these discussions throughout the course of the compact to understand the progression of the Policy Reform and Institutional Strengthening Project, and may seek to communicate directly with the implementers and evaluators of that project if documentation is not available in accord with our timeline.

2. **Longitudinal perspectives on end-user outcomes will not be possible if the location of project activities changes.** It is possible that the neighborhoods sampled for the qualitative

analysis will not benefit from the project activities from which they were meant to benefit because the location of project activities no longer covers them. Such changes to the project activities/areas will affect our ability to provide a longitudinal perspective of the effects on end users in those areas. During the initial sampling of neighborhoods for the qualitative analysis, we will also define three replacement areas. We will draw replacement households from these alternative areas and focus our questions on perceptions of changes over time.

3. **The analysis of interactions of compact activities with outside factors depends critically on the availability of non-compact related information from key stakeholders.** The implementation analysis is designed to assess to what extent other activities in the electricity sector influence the Electricity Generation and Distribution Projects. However, it may be challenging to access information on other projects that will provide enough detail to understand their impacts on MCC's investments. This possibility also is a critical risk for the quantitative evaluation designs (see Sections V.F and VI.F). We have already met with representatives of other donors working in the electricity sector in Benin and will maintain regular contact with those individuals and organizations over the life of the compact. We will conduct interviews with members of the Energy Sector Donor Roundtable as part of each round of data collection. We will also rely on our local consultants and MCA-Benin to stay apprised of developments in the country.

VIII. ADMINISTRATIVE ISSUES

Given the complexity of this multicomponent project and evaluation, careful management of the evaluation and timeline is essential. In this section, we discuss several 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 Benin's statistical committee. To obtain the certification required to conduct social sciences research in Benin, Mathematica's local research coordinator will 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-Benin 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-Benin 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

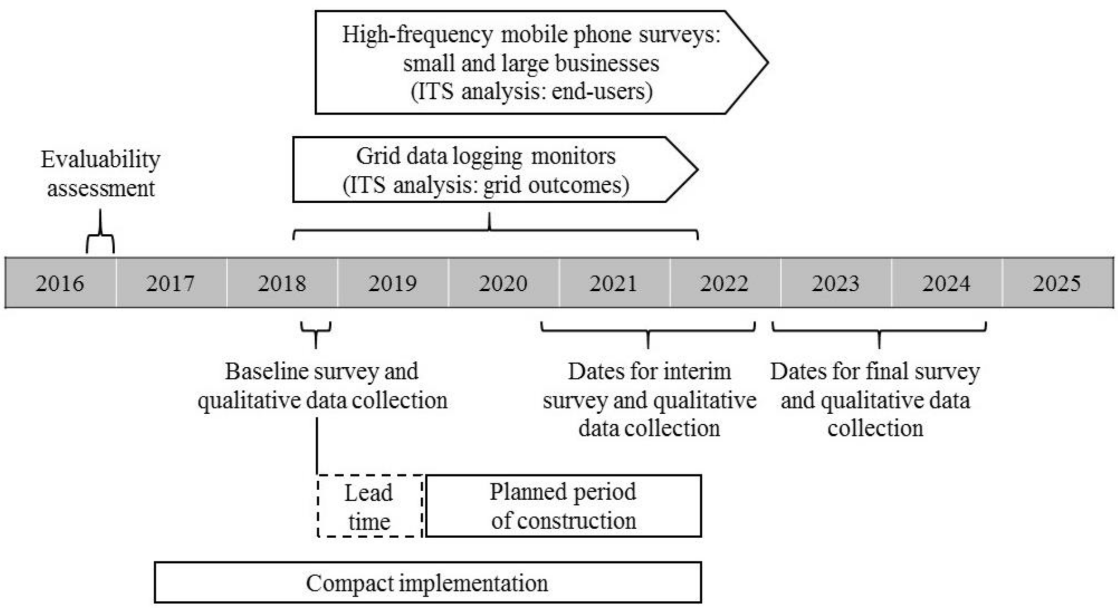
Our team brings expertise in rural electrification in Africa, an understanding of electrical grid engineering and utilities management, and decades of experience in conducting impact and performance evaluations in West Africa. As the project director, **Dr. Sarah Hughes** will be responsible for coordination with various partners, client communications, and the overall delivery of high quality products that meet MCC's needs. Dr. Hughes will provide senior advising on survey and qualitative data collection. **Drs. Arif Mamun** and **Christopher Ksoll** will serve as the project's co-principal investigators (PIs), leading the design and analyses of all evaluations for this project. Dr. Mamun will oversee the design and act as a senior advisor for subsequent analyses. Dr. Ksoll will oversee the execution of the quantitative components, including evaluation design and implementation, and communication with local stakeholders. **Dr. Anthony Harris**, serving as a researcher, and **Ms. Kristine Bos**, serving as an analyst, will support the analysis and data collection. **Dr. Evan Borkum** will provide quality assurance on all deliverables; **Mr. Denzel Hankinson** will serve as our energy economist and provide technical expertise on energy. **Mr. Kwasitse Adjogah** of Business and Technology International (BTI), an electrical engineer, will serve as our local energy expert and assist with collecting and interpreting grid data, including SAIDI/SAIFI, voltage quality, and blackout data. He will also help the team with the technical aspects of implementation activities. **Mr. Serge Kennely Wongla** will serve as a local research coordinator and data quality expert, assisting with the coordination between MCA-Benin and the implementers. He will identify and oversee local data collection partners to ensure international standards for fieldwork, ethics compliance, and data quality.

E. Evaluation timeline and reporting schedule

The evaluation activities will be ongoing over the course of the evaluation but will be concentrated around the baseline, interim, and final data collection efforts (Figure VIII.1). Baseline data collection for grid monitors and smart meters will occur as soon as possible after the entry into force of the compact and before the launch of project activities. The remaining baseline data collection will occur approximately one year before the start of infrastructure construction. The interim data collection is expected to occur in 2021 or 2022, before the end of the five-year compact and one to three years after the start of construction. The final data collection will take place in 2023 or 2024, approximately three to five years after the start of infrastructure construction. We expect the timeline to change as compact implementation evolves. In addition to these main rounds of data collection, Mathematica will collect data from high-frequency surveys and grid data-logging monitors throughout the compact's life. Figure VIII.1 does not include the data collection for the optional connection study (the proposed randomized control trial, described in Appendix A) because it is unclear when the new connections would be implemented.

Mathematica will produce written reports following each round of data collection. Contingent upon the schedule of compact implementation, the baseline report is expected in March 2019, the interim report in March 2021 or 2022, and the final evaluation report in March 2023 or 2024. Mathematica expects to complete all scheduled tasks within the nine-year period.

Figure VIII.1. Evaluation timeline and reporting schedule



Note: Dates for data collection may shift in the event that the period of construction changes.

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APPENDIX A

OPTIONAL QUANTITATIVE ANALYSIS: IMPACT EVALUATION OF STRATEGIES TO ENCOURAGE NEW CONNECTIONS

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Benin struggles not only with poor quality electricity provision, but also low connection rates. Evaluations of other electrification projects have found that households often do not connect to the grid even when they have access to an electricity line. For example, following the Transmission and Distribution Systems Rehabilitation and Extension Activity in Tanzania, only 18 percent of households connected at full price (Chaplin et al. 2017). In an expansion of electric grid infrastructure in Kenya, Lee et al. (2016) also found that household demand for grid connection was lower than predicted, even when they received very large discounts on the connection fee. Furthermore, poor households that connect to the grid can experience disconnection due to delinquent payments of the electricity tariff. In South Africa, Jack and Smith (2016) found that 21 percent of households observed for an average of 54 months were disconnected at least once due to late payments. These low rates of connection are puzzling because alternatives to grid electricity often involve significantly higher costs per kWh.[15]

MCC has proposed financing up to 10,000 new connections as part of the Electricity Distribution Project. This rollout of new connections offers MCC an opportunity to learn about (1) strategies to encourage urban households to connect to electricity; and (2) the benefits of connecting in the context of an urban community. Working with MCC, MCA-Benin, and local stakeholders, we will explore potential opportunities to conduct an impact evaluation of the 10,000 new connections, allowing us to assess the performance of alternative pricing strategies to increase connections to the grid among urban households. We propose to conduct this study as a rapid-cycle evaluation, providing MCC with both an opportunity to learn what drives lower-than-expected connection rates and rapidly identify the pricing structure that best serves the needs of poor customers in urban areas in Benin.[16] Because connection uptake can be observed very quickly, we can collect data more frequently to provide rapid, continuous feedback if users do not connect at the expected rates or disconnect or lose access after making a new connection. MCC, MCA-Benin, and SBEE could use these results to adjust the pricing strategy (including discounted connection fees and tariff rates—also called lifeline tariffs) and help more households take up and maintain connections. In addition, we propose a second analysis to assess the impacts of electricity connections on household outcomes, such as total energy use, education, and income. Because many low-income households operate small businesses, we also propose to investigate the impacts on these businesses.

This appendix is structured as follows. Section A describes potential designs for the rigorous impact evaluation. Section B describes the expected timing of the outcomes; Section C summarizes the analysis plan and statistical power; and Section D describes the data sources, sampling, and data collection plan. The appendix concludes with Section E, which provides a discussion of the proposed study's challenges and limitations.

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[15] We will use the willingness-to-pay survey to inform our design and survey instruments once we know more about the final plans for where the 10,000 connections will occur and who will be targeted.

[16] Rapid-cycle evaluation uses evaluation research methods to quickly determine whether an intervention is effective and enables program administrators to continuously improve their programs by experimenting with different interventions (Cody and Asher 2014). This type of evaluation applies rigorous methods, using administrative data to quickly provide causal impact estimates. In this case, we can compare connection behaviors between groups randomly assigned to different discounts to determine which one is most effective at increasing connections.

A. Methods

We outline three possible designs that we propose to discuss in more detail with MCC and MCA-Benin: (1) a household-level randomized control trial (RCT) (2) a cluster-level RCT, and (3) a regression discontinuity design based on household eligibility for connections within neighborhoods. We propose the household-level RCT as our preferred option because it is the most cost-effective design due to its lower sample size requirements and would therefore also allow for contrasting a variety of different pricing policies. However, we also briefly describe the other two designs and provide estimated MDIs for them.

1. Household-level RCT

Existing strategies to reduce the cost of electricity for low-income households typically provide (1) low-cost connection fees for access, (2) a discounted tariff for a specific small amount of electricity (sometimes in the form of a step or lifeline tariff), or (3) a combination of these strategies. However, there is limited evidence on whether lowering connection fees or tariffs is best for providing sustained access to a large number of poorer customers. Because many households are currently willing to pay significantly more per kWh for other sources of energy, it is possible that credit-constrained households may prefer a very low connection fee but higher per-unit rates. On the other hand, the high rates of disconnection observed in South Africa suggest that households who manage to pay for the connection fee may not be able to consistently pay for their monthly consumption (Jack and Smith 2016). We propose to pilot different pricing strategies for connecting households to the grid by working with SBEE to offer a range of (1) discounted connection fees, including a free connection; and (2) discounted tariffs, as well as selecting a control group that receives neither discount. We also propose to explore alternative strategies, such as a variety of financing options, for increasing connections in collaboration with MCC, MCA-Benin, and SBEE.[17]

Offering multiple levels of discounts would provide SBEE and GoB with information on the consequences and take-up at various levels of connection fees, and allow for tracing a rudimentary demand curve (see Lee et al. 2016). This demand curve is important because, given limited resources, it allows SBEE, MCA-Benin, and MCC to fully understand the trade-off between providing a larger discount to a smaller number of households or a smaller discount to

[17] Lee et al. (2016) estimate the cost of connections to the electricity utility in rural areas in Kenya and point out that the cost to connecting two neighbors to the grid is substantially less than twice the cost of connecting a single household. This situation also holds true in settings in which a household connection requires an additional pole (Chaplin et al. 2017). We propose to explore with SBEE whether potential customers can be provided with a connection fee discount based on the number of neighbors who also pay to connect at the same time (we would refer to it as the "neighbors connect together" plan). As this connection strategy would pass on cost savings for SBEE in setting up the connection to the customer, it might be revenue neutral for SBEE but likely less costly than offering connection fee discounts to individual customers. The "neighbors connect together" plan can also be combined with additional tariff discounts for low-income households.

We would also explore with MCA-Benin and SBEE the feasibility of offering a financing mechanism to cover the connection fee for credit-constrained households. When information from the willingness-to-pay study becomes available to us (recently conducted in Benin by MCC), we might be able assess to what extent households consider cash/credit constraint as a key barrier to connecting to the grid. If it is found to be a major barrier, offering credit financing may provide a more sustainable way of addressing the issue than discounted connection fees. Such a financing mechanism may, for example, involve fixed monthly installments paid via the usual electricity bill, or higher per-unit rates until the connection fee has been paid off.

encourage a larger number of households to connect. However, SBEE has noted that such differential tariffs can cause social tensions across communities. Mathematica will work closely with SBEE to determine what is feasible and how these challenges may be mitigated.

The comparison of households receiving a free connection with a control group not receiving a discount offers the opportunity to calculate rigorous estimates of the impact of providing a discounted connection fee on outcomes for low-income households and their businesses. This policy-relevant estimate also captures the impact of connecting to the grid on other household and business outcomes if all households in the free connection group connect and no households in the control group do so. We expect connection rates to be close to 100 percent among the group that receives the free connection, based on results from Lee et al. (2016), who found that in Kenya almost all households offered a free connection chose to connect. They also found that very few households connected at the full connection fee. Because their study was conducted in a rural setting, we are uncertain to what extent the results for the full connection fee group would transfer to the urban setting in Benin. If some households connect at the full connection fee in the control group or some do not—despite a free connection in the treatment group—the comparison between the two groups will provide an estimate of the intent-to-treat (ITT) effect of the discount.

In the two sections that follow, we describe examples of the discount offers that could be implemented as part of MCC’s rollout of new connections.

a. Discounted connection fees

We propose that SBEE pilot different levels of discounted connection fees for electricity connections as a first approach to encouraging connections across households. Among low-income households without an existing electricity connection, discounts could be assigned through a lottery with multiple treatment arms, such as the following: (Treatment 1), a free connection or full discount; (Treatment 2), a 60 percent discount; or (Treatment 3), a 20 percent discount. In addition, we would assign a fourth randomly assigned group to a control group that would pay the full connection fee. Also, since there is likely to be a desire to determine impacts for subpopulations of interest, such as households with female heads, small businesses, businesses owned by females, and low-income households, we would conduct this analysis separately by subgroup.

b. Discounted tariffs

As a second approach to encouraging household connections, we would pilot different levels of discounts in tariffs for households beyond the currently offered lifeline tariff. Specifically, we would explore a step-up tariff whereby a specified number of kWh in electricity per month would be provided at a lower cost. Any consumption above the kWh limit would be charged at the regular tariff. Practically, if the new connections require prepayment for electricity consumption, which is likely to be the case,[18] we could provide vouchers for lower-cost

[18] Prepaid electricity meters are becoming more common in sub-Saharan Africa because they reduce payment delinquency. They are available in Benin and have been used in an Agence Française de Développment (AFD) expansion of connections in the vicinity of Abomey-Calavi. Technical issues occurred with some of the meters—

electricity consumption up to the prespecified limit. To be able to compare the impacts of this discounted tariff to those of the discounted connection fee, we would set the value of the discount in the tariff to be revenue equivalent with respect to the discount in the connection fee.

As with the discounted connection fees, low-income, non-electrified households could be assigned through a lottery to multiple treatment arms, such as the following: (Treatment 1B), free kWh of electricity consumption up to the value of the connection fee; (Treatment 2B), a 60 percent discount in the electricity tariff for the same number of kWh; or (Treatment 3B), a 20 percent discount in the electricity tariff for the same number of kWh. In addition, a fourth randomly assigned group would serve as the control group. These vouchers would be linked to each household's prepaid meter, thus ensuring that only the selected household could benefit.

2. Alternative evaluation designs

Cluster RCT. If household-level randomization is not feasible we will investigate the possibility of randomizing the different discounts at the community level. Because this design requires a much larger sample size, as discussed below, it is likely that we would only be able to study either the impact of discounted tariffs or that of discounted connections fees. In the case of connection fees, discounts could be assigned to neighborhoods through a lottery with multiple treatment arms, such as the following: (Treatment 1), a free connection or full discount; (Treatment 2), a 60 percent discount; or (Treatment 3), a 20 percent discount. In addition, we would assign a fourth randomly assigned group of neighborhoods to a control group that would pay the full connection fee. All eligible households in a neighborhood could connect to the grid at the randomly assigned connection fee amount for that neighborhood.

Regression discontinuity design. Finally, if randomization is not an option, we will consider a regression discontinuity (RD) design. An RD design is possible if MCC, MCA-Benin, and SBEE provide discounted connections only for low-income households, the eligibility of households to receive connections is based on objective scoring criteria, and there are households both above and below the eligibility threshold in the targeted neighborhoods. The RD approach compares the connection rates and other outcomes of households just above and below the eligibility threshold within each neighborhood. However, the RD design requires a larger sample (Schochet 2009) than a household-level RCT and would enable us to estimate impacts only for households close to the given threshold.[19]

B. Outcomes and their anticipated time frame for realization

1. Connection rates

As noted earlier, Mathematica will conduct the analysis of the effect of pricing strategies on connection rates as a rapid-cycle evaluation. We expect that households will be able to decide

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they were not able to count electricity at the low voltages observed on the Benin network. MCA-Benin is aware of these issues.

[19] To assess the impact of different levels of discounts, it is possible to (1) set multiple thresholds within a chosen neighborhood, such that the poorest households receive the largest level of discounts, whereas slightly fewer poor households receive a smaller discount, or (2) set different thresholds within different neighborhoods.

whether to connect and pay for connection within the six-month window that we propose as a sign-up period.

We expect that this time frame is long enough for any household wishing to take advantage of the discount to do so, thus providing an accurate measurement of the impact of the discounts on connection rates. Moreover, this period is brief enough to enable us to assess how many households take up the offer to connect for a given type and level of discount. However, we will work with SBEE to determine the optimal time frame.

We will collect data on household connections through administrative data from SBEE, as described in detail in Section D. We will also conduct mobile phone surveys with some households to verify whether they have applied for, paid for, and received connections. We propose obtaining information from mobile phone surveys to (1) validate the administrative information; and (2) obtain additional information that the administrative data might not provide, such as whether (a) a household receives electricity through any other means, which also encompasses electricity produced by a generator or through a secondary connection; and (b) a newly connected household is receiving grid electricity through a secondary connection. We will also inquire whether they have encountered any problems in the connection process because one of the objectives of a rapid-cycle evaluation can be to provide rapid feedback on implementation difficulties. In addition, if households are connected, we will ask about electricity expenses to triangulate that information with the administrative data.

2. Household and small business outcomes

It may take time for households to fully enjoy many of the benefits of electricity because they may need to invest in inside wiring (which requires a safety approval) and electricity-powered appliances. There is very little evidence that explicitly addresses this question of timing as it relates to household outcomes (Chaplin et al. 2017). One study in Bangladesh found increased consumption of electricity per month over time, as well as increased household income for the first eight years after connecting (Khandker et al. 2009a). Another study in Vietnam found that children's enrollment in school increased the longer the household was connected, particularly after two years of being connected (Khandker et al. 2009b). Overall, some studies have found significant impacts on some household outcomes within one year of connection to the grid, whereas others have measured outcomes and found impacts over a longer time period (Chaplin et al. 2017).

This study will implement a final round of data collection to capture medium-term impacts on a range of household and small business outcomes, as described in Chapter IV. For this final survey, we will include shorter-term outcomes, such as barriers to connection and costs of internal wiring, energy use and electricity consumption, adult and child time use, and businesses' hours of operation. We will also include outcomes that may take longer to change, such as frequency of common illnesses, employment, and businesses' productivity and revenue. Note that the timing of the final round of data collection will depend on the actual implementation of the 10,000 new connections.

To obtain data to measure the impacts of providing a free connection on these household and business outcomes, we will conduct baseline and final face-to-face surveys with the full discount treatment and control group households. We will administer the baseline survey before offering the discounted prices to the target households. The final data collection will occur about four to five years after connections are made to study medium-term changes. Four to five years should be sufficient to capture impacts on outcomes that take longer to materialize. However, we may not be able to estimate impacts on longer-term outcomes if the connections are rolled out at the end of the compact.

C. Analysis plan and statistical power

1. Analytic approach

To determine the impacts of three levels of discounted connection fees or discounted tariffs on the likelihood of connecting to the electricity grid, we would estimate a regression model in the following form:[20]

$$connect_i = \alpha + \beta^l * T_i^l + \beta^{lm} * T_i^m + \beta^h * T_i^h + X_i{}'\gamma + \varepsilon_i$$

where $connect_i$ is a binary variable reflecting the household's decision to connect to the electric grid; T_i^l, T_i^m, and T_i^h are binary indicators whether the household was randomly assigned into the low-discount, medium-discount, or high-discount treatment arms, respectively; X_i is a vector that may include stratification variables (for example, if we stratify by small business ownership) and baseline household-level characteristics. ε_i is a random error term. The coefficients of interest are β^l, β^m, and β^h, as they capture the effects of the three levels of treatment—that is, the three levels of discounts—on connecting. If we implement both discounted connections and discounted tariffs, we would include indicators for all treatment groups and be able to compare the demand curves due to varying connection fees and tariffs.

To estimate the impact of a free connection versus a full-fee connection, we will estimate the ITT impacts of receiving a fully discounted fee connection on other household outcomes, using a regression model of the following form:

$$y_i = \alpha + \beta_h * T_i^h + X_i{}'\gamma + \varepsilon_i$$

where y_i is the household outcome being studied (for example, adult time use or electricity consumption). $X_i{}'$ includes household characteristics and outcomes measured at baseline, accounting for which would enable us to estimate impacts more precisely. The coefficient of interest is β^h, which, in the absence of spillovers, captures the impact of receiving the fully discounted connection on household outcomes versus receiving no discount. It will be very close to the average treatment effect if the connection rates for the control group are low and there are few spillovers. When there are positive spillovers, the coefficient β^h would be biased downward—that is, the estimates are smaller than the true impacts. However, in this case, the coefficient would still provide useful information on the lower bound of the potential impacts.

[20] We could implement logistic regression because the outcome is a binary variable. We would choose to implement an ordinary least squares (OLS) regression for comparability with Lee et al. (2016).

We will assess the extent of geographic spillovers by using GPS information on the location of treatment and control observations, as in the analysis conducted by Lee and colleagues (2016).[21]

2. Statistical power

We would estimate MDIs for the proposed rapid-cycle evaluation of connections as well as for the analysis of the impact of connections on other household outcomes. We provide illustrative MDIs in Table A.1. In the top panel of Table A.1, we present the MDIs for the rapid-cycle evaluation. The first row, for example, provides the MDIs in the case of either the discounted connection fee or the discounted tariff. The first row shows that with a sample size of 1,200 (300 in each of the three treatment groups and 300 in the control group), the MDI to test differences in connection rates between treatment groups that receive different levels of the discount is about 8.2 percentage points relative to a connection rate of 24 percent. The reference connection rate of 24 percent corresponds to the connection rate of the medium-discount group in Lee et al. (2016).[22] The absolute magnitude of the estimated MDI is not large; therefore, the corresponding sample size is expected to be sufficient to detect impacts of policy-relevant magnitude. The sample size of 300 households per treatment group would also have sufficient power to detect all observed differences between different treatment and control groups as estimated in Lee et al. (2016). When both a discounted tariff and a discounted connection fee are implemented, the sample size to be able to detect an MDI of 8.2 percentage points is 2,100 households instead of 1,200. The sample sizes shown may not allow us to estimate impacts precisely for subgroups of households defined by business ownership or gender of the household head. We would have to consider larger sample sizes to ensure precisely estimated subgroup impacts.

In the following rows of the first panel, we present estimated MDIs for two alternative evaluation designs we would consider—the cluster RCT and the RD design. The estimated MDIs are larger and require a larger sample size for the alternative designs. Because the RD design requires a significantly larger sample size, it is unclear whether we would be able to conduct subgroup analyses. Our ability to do so will depend on the distribution of households in the subgroups around the eligibility threshold.

The bottom panel of Table A.1 shows the MDIs for the analysis of impacts of a free connection versus a full-fee connection for longer-term household and business outcomes, where we allow for noncompliance with the treatment assignment of 20 percent—for example, because some control group households do get connected. With a sample size of 1,200 households and

[21] Baird et al. (2014) present a comprehensive design to estimate spillovers when clusters have varying treatment intensities—that is, when a different proportion of households is selected in different neighborhoods. This approach is a more rigorous alternative to the assessment of spillovers that we propose but is also more resource intensive. In addition, it requires providing a different proportion of households with discounted connections in the different neighborhoods, which may not be feasible. The variation in local treatment intensity that arises naturally through the random assignment of households to different treatment groups and the control group may already be sufficient to address connection spillovers via secondary connections. Whether it would also address social spillovers depends on the extent to which they are localized; staff from the evaluation team can explore this possibility during a site visit.

[22] We chose the reference rate to be 24 percent because this was the most conservative choice in MDIs among the connection rates observed by Lee et al. (2016) in the different treatment and control groups.

1,200 businesses for the RCT, we would be able to detect increases in consumption of energy of around 16 percent, and increases in profits for small businesses of 17 percent.

Table A.1. Minimum detectable impacts for new connections

Analysis unit/ beneficiaries	Evaluation design	Sample size	Outcome	Reference mean	MDI	MDI (% change from mean)
I. Impact of discount on connecting relative to an alternative treatment with a reference connection rate of 24 percent—Rapid-cycle evaluation						
Households	Household RCT; 3 treatment groups and one control	1,200	Connection rate (percent)	24	8.2	34.1%
Households	Household RCT; 6 treatment groups and one control	2,100	Connection rate (percent)	24	8.2	34.1%
Households	Cluster RCT; 3 treatment groups and one control	2,400 (160 clusters)	Connection rate (percent)	24	11.1	34.1%
Households	RD design; one threshold	2,400	Connection rate (percent)	24	8.2	46.2%
Households	RD design; 3 thresholds	7,200	Connection rate (percent)	24	8.2	34.1%
II. Impact of free connection versus full-fee connection on household and small business outcomes (ITT)						
Households	Household RCT; one treatment and one control group	1200	Total energy consumption (kWh)	827.6	128.5	12.4%
Households	Cluster RCT; one treatment and one control group	2,400 (120 clusters)	Total energy consumption (kWh)	827.6	194.1	18.8%
Households	RD design	4,800	Total energy consumption (kWh)	827.6	128.5	12.4%
Small businesses	Household RCT; one treatment and one control group	1,200	Monthly profit (USD)	94.5	16.0	13.5%
Small businesses	Cluster RCT; one treatment and one control group	2,400 (80 clusters)	Monthly profit (USD)	94.5	24.1	20.4%
Small businesses	RD design	4,800	Monthly profit (USD)	94.5	16.0	13.5%

Notes: We assumed a confidence level of 95 percent, two-tailed tests, 80 percent power, 10 percent sample attrition for rapid-cycle evaluation and 25 percent sample attrition for surveys, and R-squared of 0.3. For Panel II, we assumed noncompliance to be 20 percent. Information on mean and standard deviations are from the Kenya connection study (Lee et al. 2016) for connection rates, the Tanzania energy evaluation (Chaplin et al. 2017) for total energy consumption, and the World Bank Entreprenant Evaluation (Benhassine et al. 2015) for small enterprise profits. We computed intra-cluster correlations from data for the Tanzania energy evaluation (Chaplin et al. 2017).

RCT = randomized control trial; RD = regression discontinuity design; USD = U.S. dollars; kWh= Kilowatt-hour.

D. Data sources

We will obtain the data needed for the impact of different pricing strategies on connections by collecting administrative data and conducting mobile phone surveys. To estimate the impact of connections on household and small business outcomes, we will collect survey data in two rounds: baseline and final. We present an overview of these three sources of data in Table A.2 and describe the data sources in detail following the table.

To conduct the rapid-cycle evaluation of impacts on connection rates, we will rely on administrative data from SBEE. We will work with SBEE to set up a system to receive these data. The system will track applications for connections, payments for connections, installation of equipment, and billing data for households in the treatment and control groups on a monthly basis for the first six months after implementation of the discount offers in a given community, as described in Table A.2. We will also work with SBEE to obtain quarterly usage and billing data for households in the communities receiving the full discount and households in the control group. Finally, to corroborate administrative data on household connections, we will conduct phone surveys with households selected for the mobile phone survey—which may be a subset of those followed in the administrative data collection.

To assess the impact of connections on outcomes for businesses and households, we will conduct two rounds of data collection with selected households: baseline (before the implementation of activities) and final (two years after the conclusion of the compact). The two rounds of surveys will form a panel of (1) small, medium, and large businesses; and (2) households, and provide data on the range of outcomes as described in Table A.2.

Table A.2. Optional connection study sampling and data collection

Data sources	Sample size	Timing	Proposed indicators or modules
Rapid-cycle evaluation			
Administrative data collection by SBEE	2,100–10,000 households	Monthly receipt of administrative data up to six months after discounts are offered; quarterly receipt of usage and billing data for free connection group and control group up to final data collection	• Application for connection • Payment for connection • Installation of equipment • Connection • Billing data • Electricity usage
Mobile phone survey with male and female heads of households	2,100 heads of electrified households (subset of household survey sample)	Quarterly surveys after the baseline data collection	• Application and payment for primary connection • Internal wiring costs and financing • Status of connection • Incoming or outgoing secondary connection • Electricity use • Electricity expenses • Problems with connecting
RCT/RD of end-user outcomes			
Face-to-face survey with households	1,200 heads of households	• Baseline (pre-intervention) • Final (3–5 years of exposure)	• Connection • Grid and non-grid electricity consumption • Adult time use • Child time use • Household income and consumption • Appliances
Face-to-face survey with small business owners	1,200 small business owners	• Baseline (pre-intervention) • Final (3–5 years of exposure)	• Connection • Profitability • Opening hours • Input mix and capital investment • Electricity costs • Investment in electric equipment

Below we discuss our sampling procedures and the data collection plan for each data source.

1. Sampling

Mathematica will work with SBEE and MCA-Benin to select households for the connection studies. In consultation with SBEE and MCA-Benin, Mathematica will conduct a household listing and eligibility survey in neighborhoods in Cotonou and other project areas specified by MCC, MCA-Benin, and SBEE for the offer of new electricity connections. The listing exercise will collect the information needed to determine which households should be eligible for a discounted price connection. Specifically, the listing and eligibility survey could include information on the household’s contact information, GPS location, basic demographics (including GSI information), grid connection status, and other characteristics needed to determine low-income status. The enumerators will visit each household in the area to collect this information.

Given that MCA-B (through SBEE) is likely to distribute 10,000 connections, we may need to sample from the group of all beneficiaries to reduce data collection burden. To that end, after we randomly assign households into the various treatment and the control groups, we would draw a sample of households for the rapid-cycle mobile phone survey. For the outcomes impact evaluation data collection, which would be conducted separately from the rapid-cycle mobile phone survey, we would sample additional households from the free connection treatment and full-fee control groups. This larger sample will allow us to detect impact on socioeconomic outcomes. Our mobile phone survey sample will not be large enough to detect impacts on socioeconomic outcomes. To conduct an analysis by subgroups, such as households with female heads or those with small businesses, we would stratify the sample by subgroup and sample a sufficient number of households within each stratum.

If the **cluster RCT design** were to be implemented, we would first consult with MCA-Benin and SBEE to identify possible neighborhoods for new connections. We would identify a large enough number of neighborhoods to plausibly expect more than 10,000 households eligible for receiving the discounted price connections. We would then conduct a listing of households within these neighborhoods to determine eligibility and randomly assign neighborhoods to treatment and control groups. Within neighborhoods, we would draw a stratified random sample with strata defined as in the household-level RCT.

If the **RD design** were to be implemented, we would sample households just above and below the threshold for eligibility for benefiting from discounted connections (or tariffs) to form the treatment and comparison groups. With multiple thresholds for multiple levels of discount, we would sample from around each of the thresholds.

2. Data collection approach

a. Administrative data on connections and electricity usage from SBEE

We will work together with SBEE and MCA-Benin to collect the household listing and eligibility data. In particular, we will need to ensure that households receive a unique household ID in the listing and eligibility survey that can be linked to their application for a connection, and subsequently to whether they received a connection and their electricity usage. This information is crucial because our rapid-cycle evaluation will require us to obtain timely information on households' connection status to inform MCC, MCA-Benin, and SBEE about take-up rates under the different options. If the use of household IDs is respected, the administrative data will be of sufficient quality to provide comparisons between the different treatment groups. It is much less clear, however, to what extent we would be able to track the control group because its members will not receive a discount by providing their ID.[23] Moreover, the administrative data will not provide information on secondary connections. To collect information on control households and the extent of secondary connections, and to assess the reliability of the administrative data, we propose to conduct additional mobile phone surveys of households and their businesses on a quarterly basis; we also will collect information on whether the household is connected and has incoming or outgoing secondary connections. Our understanding is that secondary connections are visually evident and users usually are not hesitant to reveal their connection status. We will,

[23] One mitigation strategy would be to provide a minimal discount to the control group—perhaps 5 percent—so that any household in the control group would also have the incentive to ensure that its household ID is noted in the application. The other strategy outlined here is to validate the data by quarterly mobile phone surveys, which would provide the additional information on secondary connections.

however, balance the need for quarterly data collection against resources available by reducing the sample size for the mobile phone survey if the administrative data are reliable and no evidence exists to suggest that secondary connections play an important role in the evaluation areas.

b. Mobile phone survey

We will contact households and small businesses quarterly during the months immediately following the baseline data collection. To contact households and small businesses over this time, we will use the contact information obtained through the household listing and eligibility survey. Specifically, we will ask for multiple contact phone numbers, as it is common in developing countries to switch phone number and network when there are special deals available from another network. We describe our quality assurance procedures for a mobile phone survey in detail in Chapter VI.

c. Household and small business survey

If possible, in addition to the survey development, we also will coordinate the data collection activity with the business and household surveys described in Chapter VI. We describe our quality assurance plan for the business and household data collection in more detail in Chapter VI. We will complement the business and household surveys with qualitative data captured through in-depth interviews with business owners and FGDs with household members (see Chapter VII).

E. Challenges

There are two primary identification challenges for the household-level RCT—noncompliance and spill-overs. In addition, the ability to measure medium-term effects within the anticipated period of the evaluation will depend on the timing of the new connections.

1. A possible threat to our study design would be **noncompliance** – that is, if households selected as part of the control group manage to receive discounted connections. We will work closely with SBEE to ensure that this possibility does not happen. However, it is likely that some households in the control group were already connected or will connect to the grid even at the full connection fee. Depending on the extent to which control group households connect on their own, our impact evaluation will estimate ITT impact instead of the impact of a connection.

2. Because treated and untreated households will be from the same neighborhoods, it is possible there will be **spillovers from households with connections to those without them.** They are of two types: (a) connection spillovers and (b) social spillovers. First, about a third of connected households are connected via secondary connections, whereby they access electricity through an extension cord from a household with a primary connection to the SBEE network (MCC 2015). Households connected though a secondary connection often pay a fixed monthly rate regardless of actual consumption, but typically pay a much higher rate per kWh (sometimes twice as much) than if they were connected directly (MCC 2015). We will specifically investigate whether there are secondary beneficiaries to the new direct connections by including questions about outgoing secondary connections on our surveys. Second, social spillovers occur when households in the control group benefit from

electricity—for example, because they charge their phone at a connected neighbor's house, their children study at night at the connected neighbor's house, or they benefit from outdoor lights installed by a connected neighbor. Our questionnaire will also investigate the extent of social spillovers. If we find evidence of spillovers, the estimated impacts would be lower-bound estimates.

3. If **SBEE provides the low-cost connections only during the final year of the evaluation,** we will be able to measure only short-term impacts during the evaluation period. If this circumstance occurs, we will discuss with MCC whether we should postpone the final evaluation to the latest point possible during the evaluation period or extend the evaluation.

4. The **set of possible interventions may be limited** by what SBEE and the regulator responsible for tariffs are willing to implement. The establishment of new tariffs, even on a pilot basis, will need to involve the regulator. We will consult closely with both SBEE and the regulator responsible for setting tariffs to explore which interventions can feasibly be randomized as part of the evaluation. Depending on the target population for the 10,000 connections, it may be possible to subsidize existing tariffs, adjust them, or provide credit support for connections.

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APPENDIX B

DETAILED SUMMARY OF PLANNED ACTIVITIES AND INVESTMENTS

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Table B.1. Summary of Electricity Generation and Distribution Project activities and investments

Project	Activity	Sub-activity name	Investment	Investments detailed	Location
Generation	PV generation activity		PV plant	New 15 MW PV plant	Parakou
Generation	PV generation activity		PV plant	New 5 MW PV plant	Natitingou
Generation	PV generation activity		PV plant	New 10 MW PV plant	Djougou
Generation	PV generation activity		PV plant	New 15 MW PV plant	Bohicon
Generation	Hydroelectric generation activity		Hydroelectric plant rehabilitation	Rehabilitate the Yeripao hydropower plant, increasing capacity from 505 kW to 1 MW	Yeripao (Natitingou)
Generation	Potential thermal power plant		Thermal plant	25 MW Thermal plant	Maria Gleta
Distribution	Regional grid strengthening activity	Natitingou network modifications	Upgrade existing Natitingou distribution substation	New 161 kV infeed, 161 kV switchgear, transformer at existing substation	Natitingou
Distribution	Regional grid strengthening activity	Natitingou network modifications	New 33 kV substation to link PV plant	Installation of 33kV substation; ~10km of 33kV OHL from Berecingou	Natitingou
Distribution	Regional grid strengthening activity	Natitingou network modifications	Optical fiber link between Berecingou and Yeripao HPP	Optical fiber connection from Berecingou to Yeripao HPP	Natitingou
Distribution	Regional grid strengthening activity	Natitingou network modifications	Upgrading 80km of rural lines	Upgrade 80km of OHL MV lines from 15/20 kV to 33 kv to rural areas around Natitingou (including transformers)	Natitingou (rural)
Distribution	Regional grid strengthening activity	Parakou network modifications	Substation modifications to link PV plant	Connect 33 kV switchgear to grid	Parakou
Distribution	Regional grid strengthening activity	Parakou network modifications	Upgrading 120 km of rural lines	120 km of OHL MV upgraded to 33 kV from 20 kV (including replacement of transformers)	Parakou (rural)
Distribution	Regional grid strengthening activity	Parakou network modifications	Direct connections for industrial consumers	Install 20 kV direct MV connections for 10 largest industrial consumers.	Parakou
Distribution	Regional grid strengthening activity	Djougou network modifications	Substation modifications to link in PV plant and utilitze 161 kV line to Natitingou	Upgrade existing 161 kV connection to full switchgear, with OHL loop-in and loop-out of lines from Kara to Parakou	Djougou
Distribution	Regional grid strengthening activity	Djougou network modifications	Upgrade 140 km of rural lines	140 km of rural OHL MV lines upgraded from 20 kV to 33 kV. Transformers upgraded as well.	Djougou (rural)

Project	Activity	Sub-activity name	Investment	Investments detailed	Location
Distribution	Regional grid strengthening activity	Porto Novo Network modification	Second 63 kV connection between Porto Novo and Akpakpa (Cotonou)	Construct new 63 kV double busbar feed in Porto Novo to receive power from direction of Vedoko, which will come via Akpakpa. 63 kV line to connect.	Porto Novo --> Akpakpa
Distribution	Regional grid strengthening activity	Porto Novo Network modification	Upgrade substation at Repartition D2 linked to 63 kV line between Akpakpa and P.N.	H-config 63 kV side, 63/15 kV 20 MVA transformer, busbar for 15 kV feeder, 15 kV cable, building.	Cotonou (East)
Distribution	Regional grid strengthening activity	Porto Novo Network modification	Upgrade 130 km of rural lines	Rural connections and upgrading of OHL from 15 to 33 kV (130km)	Porto Novo (rural)
Distribution	Cotonou grid-strengthening activity	Cotonou capacity increase	New 63 kV double busbar switchgear to feed 63 kV line to Gbegamey->Akpakpa.	Upgrades to Vedoko substation. Including: 161/64 kV, 2x100 MVA transformers 161/15 kV, 40 MVA transformers for local supply	Vedoko
Distribution	Cotonou grid-strengthening activity	Cotonou capacity increase	63 kV line from Vedoko to Akpakpa, via 3 new and upgraded substations	63 kV line between Vedoko and Akpakpa, via Gbedjrombede, Saint Michel and Repartition D1 (Croix Rouge). Replaces existing 15 kV lines feeding substations from Vedoko.	Vedoko-Akpakpa
Distribution	Cotonou grid-strengthening activity	Cotonou capacity increase	Creation of Gbedjrombede substation	2 63/15 kV step-down transformers at 20 MVA, with 15 kV single busbar system with 10 incoming and outgoing feeders	Gbedjrombede (Cotonou Centreal) West of entrance to lagoon
Distribution	Cotonou grid-strengthening activity	Cotonou capacity increase	Upgrade Repartition D1 substation	2 63/15 kV step-down transformers at 20 MVA, with 15 kV single busbar system with 10 incoming and outgoing feeders	East side of Lagoon entrance (Cotonou)
Distribution	Cotonou grid-strengthening activity	Cotonou capacity increase	Cable ring to Cadjehoun and Fidjrosse substations (63 kV)	Replacement substations at both locations: 2 63/15 kV step-down transformers at 20 MVA, with 15 kV single busbar system with 10 incoming and outgoing feeders	Cadjehoun and Fidjrosse (south of Vedoko)
Distribution	Cotonou grid-strengthening activity	Cotonou capacity increase	Upgrade to Vedoko station for direct link to Abomey-Calavi	Direct 63 kV connection to the Abomey-Calavi distribution project (will be 2 new substations), bypassing Maria Gleta switchgear.	Cotonou
Distribution	Cotonou grid-strengthening activity	Cotonou capacity increase	10,000 new connections	10,000 connections, including 15 kV lines to supply LV connections and step-down transformers for consumers.	Cotonou, possibly west of Fidjrosse substation

Project	Activity	Sub-activity name	Investment	Investments detailed	Location
Distribution	Cotonou grid-strengthening activity	Cotonou reliability	Transmission grid connection at Maria Gleta	161/63 kV step-down transformer at Maria Gleta substation (being built as part of Abomey-Calavi project). 2 x infeeds. 2 63 kV double busbar feeder at Maria Gleta switchgear. 2 x 161/63 kV 100 MVA transformers to be installed to feed Abomey-Calavi	Cotonou/ Abomey
Distribution	Cotonou grid-strengthening activity	Cotonou reliability	Replacement of 15 kV substation Anceint Pont with 63 kV infeed	Replace Ancient Pont 15 kV substation with 63 kV step-down substation. Loop-in and out 63 kV line originating at Vedoko. 2 x 63/15 kV step-down transformers at 35 MVA. 18 feeders for 15 kV network.	Ancient Pont (Cotonou)
Distribution	Cotonou grid-strengthening activity	Cotonou reliability	Upgrade of 15 kV substation St. Michel, with future option to allow 63 kV infeed	Upgrade Saint Michel substation, with potential space for future upgrade to 63 kV infeed. Upgrade to new double busbar configuration, with option for future 63 kV infeed. Eight feeders for 15 kV network.	St. Michel (Cotonou)
Distribution	Cotonou grid-strengthening activity	Cotonou reliability	Upgrade OCBN (Maersk) substation, with potential space for future upgrade to 63 kV infeed.	Upgrade to new double busbar configuration, with option for future 63 kV infeed. Eight feeders for 15 kV network.	OCBN (Maersk)
Distribution	Cotonou grid-strengthening activity	Cotonou reliability	Re-configure and upgrade Seme substation	Install coupling switch to 63 kV busbars, that currently serve industrial and public consumers separately. Add 63/15 kV 20 MVA step-down. Loop-in and loop-out Akpakpa to Porto Novo 63 kV line.	Seme (east of Akpakpa)
Distribution	Cotonou grid-strengthening activity	Cotonou reliability	Modify and re-configure Bohicon substation	Additional 63/15 kV transformer at 20 MVA for Bohicon, with 63 kV feeder. Link with PV plant.	Bohicon
Distribution	National electricity dispatch activity	NDCC	Construct national distribution control center		Gbegamey
Distribution	National electricity dispatch activity	NDCC	Preparation work for distribution substations and installation of AMR and AMI meters for large industrial customers	Modification of distribution substations (63, 33, 20 and 15 kV) so that SCADA can control circuit breakers and measure.	National
Distribution	National electricity dispatch activity	NDCC	Install monitors	Installation of monitors between step-down transformers to continuously log voltage, power, current, and power factor.	National
Distribution	General activities	General network modifications	Power factor correction equipment	4 x 1.5 MVAr units and 16 x 3 MVAr capacitor banks.	National
Distribution	General activities	General network modifications	Sectionalizing switching equipment	30 Sectionalizing switches in Cotonou	Cotonou

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APPENDIX C

NETWORK SCHEMATICS

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Figure C.1. Parakou network schematic

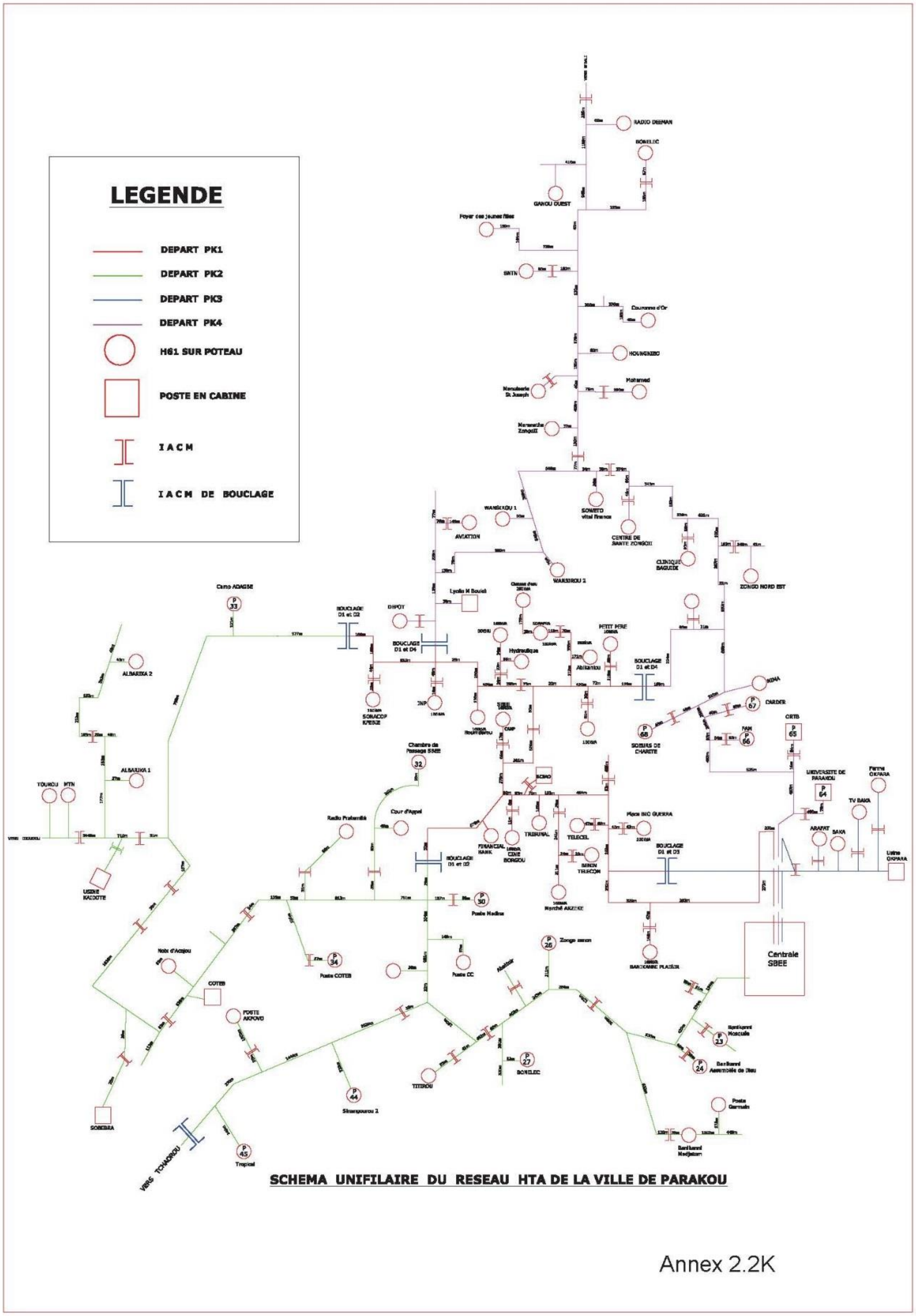
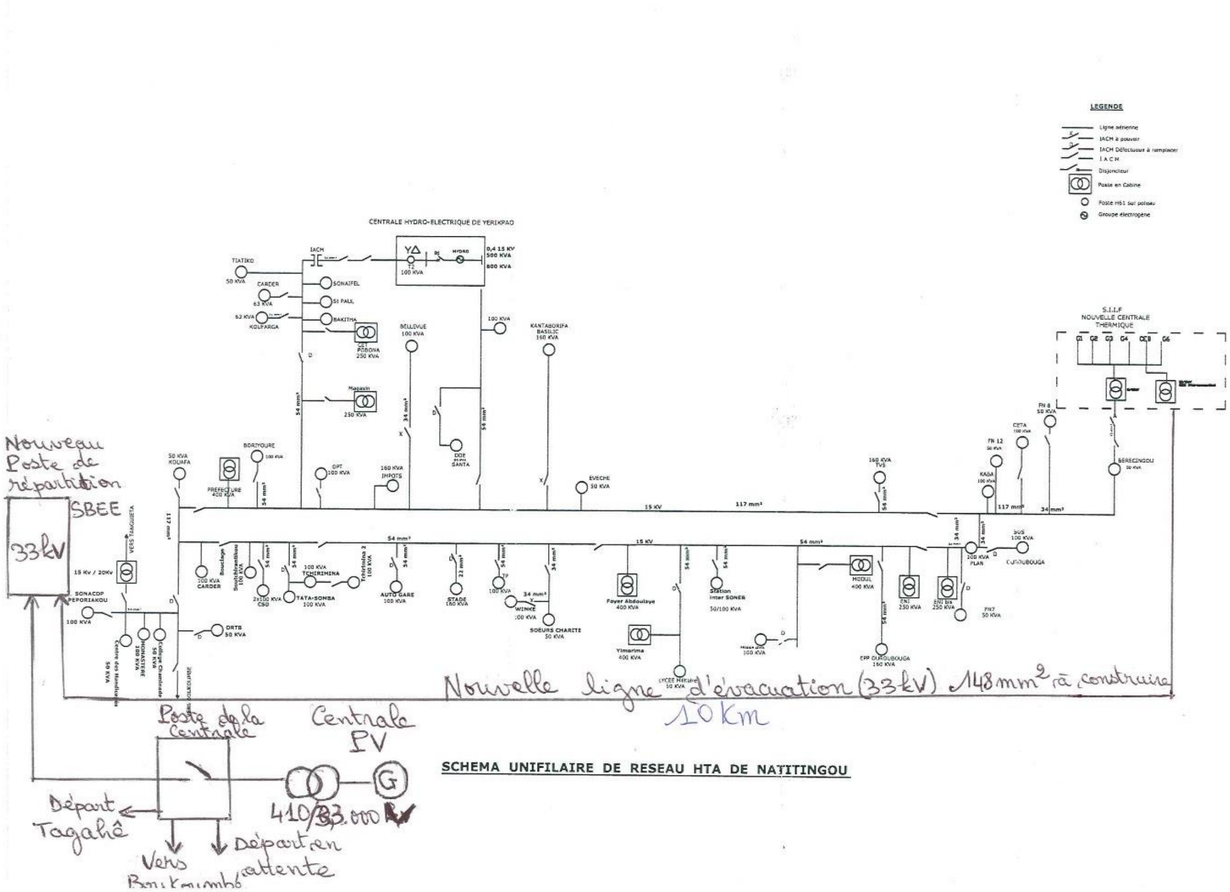


Figure C.2. Natitingou network schematic



APPENDIX D

STAKEHOLDER COMMENTS AND MATHEMATICA RESPONSES

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This table shows the comments from MCC and other stakeholders, as well as the responses given by Mathematica. The names of the commentators have been removed for anonymity. Please note that some page numbers may not match the revised version of the EDR, due to edits to the document.

Table D.1: Stakeholder Comments on the Design Report and Mathematica Responses

#	Chapter	Comments	Response
A. Comments from MCC			
1		**Overall:** - Please make sure that you are using MCC's standard template for EDR.	The EDR follows MCC's standard template, with a few deviations that were discussed with MCC prior to submission of the original draft, given the complex nature of the evaluation. Namely: - The literature review is its own chapter. - Rather than have one chapter for the quantitative analysis, we have separated the quantitative section into 3 chapters: grid outcomes, end-user outcomes, and optional connection study. - We included challenges separately for each chapter. As noted, the first draft did not include the budget. The final version will be accompanied by a budget modification request.
2		**Overall:** The report is missing the annex outlining the evaluation budget (unless this was submitted separately). The EMC needs to understand how much the proposed evaluation will cost (breaking out data collection costs). We particularly need to know the estimated cost of the connections IE before we make a decision.	The revised version of the report includes the evaluation budget.
3	I - Intro	**Page 1:** Regarding Benin's ranking in net electricity generation: Generation or consumption? What about per capita measure? But if the strategy of the country is imports (which has been the case), they would rank low on this indicator.	The statistic presented is generation. We have reorganized this section to make it clear that, because Benin's generation capacity is so low, it has relied heavily on imports.
4	I - Intro	**Page 1:** It has been a while since I have looked at financial statements for SBEE but I seem to recall that they operated in the black while CEB operated in the red due to the low bulk tariff from CEB to SBEE; SBEE looked profitable while the losses were piling up in CEB, the bi-national company.	Based on recent reports from other donors, it appears that SBEE's financial situation has improved over the last few years, but it still has increasing deficit. The text in this section has been modified and a reference added.

#	Chapter	Comments	Response
5	II- Overview of Activities	**Page 3:** Please reference the various objectives noted in the Compact. The main outcomes that this evaluation is designed around should link to these objectives. When this evaluation closes, MCC will need to report measurements related to the objectives below and our goal of poverty reduction through economic growth. As such, please make sure the Objective-level outcomes are specified in the appropriate places (I think they are for the most part and I've tried to note where they might be missing) and be sure to include a HH and business income measure. Alternatively, if MPR believes trying to measure incomes is not cost-effective or if the evaluation will not be powered to detect feasible impacts, this should be explicitly noted in the EDR so that we don't wonder why we didn't measure this when we get to the endline. Objectives noted in Compact: The objective of the Program (the "Program Objective") is to expand business production and productivity, generate greater economic opportunities for households and improve the capacity to provide public and social services by improving the 2 quantity and quality of the supply of electricity. Gx and Dx Projects: The Objective of the Electricity Generation Project is to: (A) increase the hours of operation for businesses and public and social services; (B) reduce reliance on costlier sources of energy; (C) reduce losses of products and perishable goods; and (D) improve productivity for users of electricity (the "Electricity Generation Project Objective") Somewhat relatedly, the report should maybe have a table that summarizes which key outcomes will be assessed via the IE and which only by the PE. We can discuss this if it seems like overkill.	**Income:** We propose to measure business income for the pre-post surveys, as well as the optional 10,000 connections study. For households, we have proposed measuring proximate outcomes that may eventually lead to increased household income, but not household income itself. We do not believe it is worth the time and cost to measure household income for several reasons. First, we don't believe that there is a obvious link between more/better power and wage increases. Second, this will lengthen the questionnaire, and our experience shows that in urban areas it is often harder to get respondents to sit down for a long period of time. Any changes in income for household businesses will be captured through our small business surveys. Finally, household income would only be included as part of the pre-post analysis, which will not provide causal impacts. Therefore, we believe that including household income in the survey would not present a large learning opportunity for MCC. We have added a footnote In Chapter IV, section B that explains that we will not measure household income and why. **Research questions with PE and IE:** Table IV.2 provides information on which research questions are answered through a PE and an IE
6	II- Overview of Activities	**Page 3:** FYI – EIF occurred June 22, 2017.	This has been updated.
7	II- Overview of Activities	**Page 3.** This is a finer point – the solar PVs may be constructed by independent power producers with MCC funds used to hire a transaction advisor and possibly put in some equity. Under consideration and RFP to hire IPP consultant has been launched.	We added a footnote in Section II.A to mention this possibility.

#	Chapter	Comments	Response
8	II- Overview of Activities	**Page 3**: Recommendation for evaluation of both projects: Mathematica should have the N-E Team's 2 Mission Reports from 2016 and its Report of Findings (final, November 2016), to understand some of the productive activities and existing entrepreneurs (or productive groups) that are in these areas and would likely be able to benefit from the improved power service quality in the area (as either control groups or beneficiaries).	We have reviewed the documents and will use the findings from the mission report as we develop our instruments.
9	II- Overview of Activities	**Page 3:** Regarding "As part of the project preparation, MCA-B and its contractors": Or IPPs.	This has been updated.
10	II- Overview of Activities	**Page 4:** The regional grid strengthening as approved in the compact has been pared back such that certain elements listed here have been eliminated – e.g., upgrade rural lines, connect industrial customers in Parakou. We should provide the final approved budget. However, the design consultant may design more than the minimum so that we have prepared investments to fund should we have available funding.	These elements have been removed from Table II.1. We also added a footnote in Section II.A to explain that these elements were originally included in the compact but have since been dropped.
11	II- Overview of Activities	**Page 4:** Missing "kV" from cell starting "Upgrade Vedoko substation…"	This omission has been fixed in the text.
12	II- Overview of Activities	**Page 4:** "Expansion of access road" is currently in question	We revised the text to indicate that the expansion of the road is only a possibility.
13	II- Overview of Activities	**Page 4:** The plan was to end up with 32 MW of capacity from thermal upgrades. Not certain of source of 80 MW figure.	This error has been corrected.
14	II- Overview of Activities	**Page 8:** Because of concerns on our part about the maintenance management practices at SBEE, there is a requirement to put in place a maintenance management system at SBEE and doing so is a CP to certain other compact investments.	We added a sentence at the end of Section II.A to describe this requirement.
15	II- Overview of Activities	**Page 8:** Was there a combined ERR for multiple projects or did you take an average? Please specify whether which parts of the Compact this ERR covers.	The ERR figure cited in the EDR was from the original compact. We have revised the text to explain that this ERR includes all compact activities except the off-grid activities.
16	II- Overview of Activities	**Page 9:** The ERR model for the compact assumes that benefits, in the form of increased consumption"" specify that this is electricity consumption.	This has been revised.
17	II- Overview of Activities	**Page 9:** [The ERR] It also includes costs of MCA admin and M&E budgets.	This has been added.

#	Chapter	Comments	Response
18	II- Overview of Activities	**Page 9:** [Regarding the last paragraph on the ex-post ERR]: This section needs to be more detailed. MPR is asked to calculate an independent estimate of the post-compact ERR. If you are confident in MCC's model, you can simply update the inputs. However, MCC needs to know what specific methodology you plan to use (whether the MCC economist's or your own model) The report needs to be explicit about whether it is measuring all the benefit streams modeled in the CBA. It would be best for you to include a table here listing the benefits and noting whether they will be measured or not. If not, that should be highlighted and justified so that the EMC can make an informed decision. In addition, even if you update the MCC CBA model, I think you will need to consider whether the WTP measures need to be updated at interim or endline. Are you planning to collect the necessary information through the business/HH surveys? If so, that should be explicit (i.e. that we will be able to re-estimate the demand curve through these surveys / consider whether WTP parameter in the CBA needs to be updated). Ideally, the later methodology section would include a sub-section detailing how you are planning to conduct the CBA to calculate the ERR. (MCC's guidance on this is evolving, so we understand this was likely not clear to you)	We have added text to this section of the report to clarify that, as MCC's revised ERR model becomes available, we will develop a methodology for updating the ERR. Until we are able to examine the full, updated ERR model, we cannot say whether our methodology will involve simply updating the model inputs, or whether it will entail development of a separate ERR model.
19	II- Overview of Activities	**Page 11:** I have yet to see a loss percentage for African utilities less than 20% (I have not looked at SA data however) and in many countries it is higher than that. Perhaps 12-16% was for technical losses on top of which there would be non-technical losses?	We found that estimates ranged fairly widely across sources. We have updated the text to present a range that seems more accurate, from 18 to 30 percent for SSA as a whole.
20	III - Lit review	**Page 14:** NRECA-ENERGIA Mission 1 and 2 Reports (2016) and the Report of Findings (November 2016) would provide female/male entrepreneurs' opinions on many of these issues, in Cotonou and in the towns where the PV generation projects are being installed.	We have reviewed the documents and will use the findings from the mission report as we develop our instruments. We have also emphasized in the report where we expect to learn more about gender and social inclusion.
21	III - Lit review	**Page 14:** Lower Reliance on Costlier Energy Sources. I would like to hear from others. -Should we use the $0.23 (current cost of KWh for grid) as our end-of-compact target? This is one of our long-term outcomes, and the M&E Plan would require this	This comment does not require a response from Mathematica.

#	Chapter	Comments	Response
22	III - Lit review	**Page 15: Increased Productivity for Businesses**. Is there any study in the region with economies similar to the Benin's? Manufacturing is not very developed in Benin (perhaps not as much as in West Bengal and India). **Maybe using a more similar country (within the ECOWAS/WAEMU region) for comparison could be more appropriate**	We agree that it would be more appropriate to cite literature from other countries in the region. However, there was very limited literature specific to West Africa on the effects of reliable electricity on business productivity.
23	III - Lit review	**Page 15: Reduced Losses of Products and Perishable Goods.** I understand that there is little evidence on this. But that issue came up several times during our focus group discussions 2 years ago across the country. Although no respondent could objectively provide quantified data on the amount of their losses, they had raised that as a major problem and a constraint to business growth. I would be curious to see how the evaluation could capture this in the baseline studies and subsequent studies. More specifically, on the destruction of products, it'd good to analyze the quality/types of equipment or devices being used by energy users. There are cases where people import machines or equipment not suited for the voltage or intensity produced by the utility (e.g. a 120v being used for a 220v outlet), which could cause damages to those products. Separating cases like these from the legitimate damages caused by voltage quality could be useful	We intend to measure losses related to poor electricity quality, including equipment damage and loss of perishable items during the phone surveys and we can explore the possibility of collecting detailed information on electrical equipment, but it may be hard to get accurate data from respondents.
24	III - Lit review	**Page 16: Improved Education Outcomes. Any chance one could use the 10,000 participants in the Cotonou grid extension as a way to test this?** This debate has taken place amongst the Benin Country team during the development and designing of the projects. Anecdotal examples have been used on both sides. A more rigorous studies of those participating in our grid extension program could be a target population. Same for the previous result (i.e. potential cost saving through Reduction of Reliance on Costlier energy sources)	We could consider including education outcomes as part of the survey for the optional connection study, but we will have to weigh the costs and benefits of a lengthier survey.
25	IV - Evaluation design	**Page 19:** [Regarding RQ 3] Consider IPPs and investment by WAPP.	This has been added.
26	IV - Evaluation design	**Page 20:** Any questions on how other projects (Policy Reform and Off-grid) not being covered in the EDR could affect the outcomes of those being considered? And how their success (or failure) could affect the outcomes of those being evaluated?	We will track progress on the other components of the compact, but adding research questions on the Policy Reform and Off-grid component is beyond the scope of this evaluation.

#	Chapter	Comments	Response
27	IV - Evaluation design	**Page 20. [Regarding RQ6]:** Would it not be more appropriate to say: “To what extent did…”. Otherwise, this reads as a yes/no question. Consider adding a question about reserve margin (in the event installed capacity overtakes demand).	We added "To what extent did…" to the beginning of this question as suggested. We feel this added flexibility in the research question now allows for the potential of a reserve margin.
28	IV - Evaluation design	**Page 20. [Regarding RQ12]**: Are you looking at the same outcomes as in RQ10?	We will look at the same outcomes; this has been clarified in the table.
29	IV - Evaluation design	**Page 21:** For end-user outcomes: add considerations of expanded business (increasing use of electricity) for businesses, improved household incomes after electrification, etc.	A more complete list of outcomes is provided in Table IV.2. That list includes business and household productivity. However, we do not plan to measure household income, and our reasons for this decision are described in response to comment A5 above.
30	IV - Evaluation design	**Page 21:** I assume [the implementation analysis] will be ex-post (i.e. no data collection during compact implementation). Some evaluators have assessed implementation at various stages. Please specify for the people who don’t read further in the report.	We clarified in the text that we will assess implementation plans prior to start of activities and actual implementation at two points in time. Please see also see our response to comment A164, where we discuss the possibility of including structured observation as part of the implementation analysis.
31	IV - Evaluation design	**Page 21:** Will [the qualitative evaluation] be phased to build on the quantitative data collection (or, alternatively, to inform a quantitative survey)? Will it be pre/post or ex-post? Please specify here in the intro.	We will collect the qualitative data to build on the quantitative data-collection, and qualitative data will be collected at multiple points in time. This has been clarified in the text.
32	IV - Evaluation design	**Page 21:** FGDs participants should represent the range of stakeholders including women, poor, youth, other GSI-target groups.	We added two paragraphs to this section that explain how the evaluation will incorporate the GSI requirements from the RFP. This includes an explanation that our FGDs will include a range of stakeholders so that we can fully understand the factors affecting any experienced benefits of the projects.
33	IV - Evaluation design	**Page 21:** I think we should be clear where we are expecting to collect data from either the data monitoring system to be installed as part of the distribution design work or the dispatch center, if in fact we are relying on those for data.	In Table IV.2, we clarified that the data source is "High-frequency measurement of grid outcomes from grid monitors installed on the distribution system and smart meters"
34	IV - Evaluation design	**Page 21:** RQ1, 2, 3 Data sources, Add beneficiary consultations	To the extent that beneficiaries mention that project outcomes are poor they might also have thoughts on potential reasons, which we would explore in RQ9 & 10. But, we would not expect that beneficiaries would provide input on these macro questions related to project design, sustainability, and outside factors.

#	Chapter	Comments	Response
35	IV - Evaluation design	**Page 21:** Outcomes and themes for RQ 3: What about private sector investment?	This has been added.
36	IV - Evaluation design	**Page 22:** [RQ4] In order to calculate the benefits from generation, financial information from SBEE and/or generation and distribution companies will be needed	We don't believe that collecting information on the finances of generation and distribution companies will be possible. However, we do propose to collect information on the cost and volume of domestic generation and imports.
37	IV - Evaluation design	**Page 22:** [RQ4] Presumably, the surveys will measure income increases. It will be most important to collect GSI disaggregated data.	Please see our response to comment A5 for a description of why will not measure household income. We agree that collecting GSI disaggregated data is an important component of the evaluation. Rather than describing the GSI disaggregation in each table cell, we added two paragraphs preceding the table that describe our approach to GSI disaggregation and analysis.
38	IV - Evaluation design	**Page 22. [RQ6]** Consider adding a question about reserve margin (in the event installed capacity overtakes demand).	We changed the question to, "To what extent did…" which captures the possibility of excess supply.
39	IV - Evaluation design	**Page 22. [RQ6]:** What SBEE data are we referring to and is it available? Or are we relying on the data collection system?	GOPA-Intec, the distribution design consultant, has proposed a data-collection system to collect information on the sources of outages at the in-feed level. These data exist at SBEE and are reported to headquarters on a weekly basis.
40	IV - Evaluation design	**Page 22. [RQ6]:** This [SBEE data as a data source] is not explicit in terms of measurement of 'suppressed' demand, including self-suppressed demand (when consumers go for alternative sources of supply)	For customers connected to the grid, we will be able to obtain measures of the amount of demand suppressed due to outages by examining their overall grid and non-grid electricity consumption. Through an assessment of non-grid electricity consumption, we can measure the current unmet electricity demand of households who have access to non-grid electricity, but not a grid connection. However, we won't be able to know their potential consumption if they were to be connected. For households that have no access to electricity, we will not be able to assess demand.
41	IV - Evaluation design	Why focus only on businesses and not households? Is such a focus consistent with the theory of change?	We corrected this to cover households as well as businesses.

#	Chapter	Comments	Response
42	IV - Evaluation design	**Page 22. [RQ8]:** Would you also interview SBEE line staff, especially those responsible for taking care of technical problems? This may provide some useful qualitative information for understanding whether response time is decreasing/increasing?	We agree, and have added interviews with SBEE line staff as a data source in the table.
43	IV - Evaluation design	**Page 22. [RQ8]:** What SBEE data are we referring to and is it actually available?	GOPA-Intec has proposed a data-collection system to collect information on the sources of outages at the in-feed level. These data would allow us to understand which outages are caused by technical failure.
44	IV - Evaluation design	**Page 22. [RQ9/10]:** The evaluation method says “quantitative”, but the data sources seem qualitative to me. Same comment for RQ10. Should outcome be "energy sources and expenditures" rather than only "energy sources?"	We consider surveys to be quantitative data, because we collect data from enough respondents to allow for statistical analysis. We added "expenditures" as well.
45	IV - Evaluation design	**Page 22. [RQ10]:** Should test if poor households would participate in use of phones for surveys? Will they be verbal or written? Will there be a control group? Determined how? Important to plan for GSI disaggregation	Surveys will administered through a phone call conducted by an enumerator. We will pretest the instrument and the sampling in order to understand response rates and cell phone ownership rates. For this evaluation component, there will not be a control group. Rather we rely on the ITS design to provide a counterfactual. We have added text about GSI disaggregation preceding the table.
46	IV - Evaluation design	**Page 22. [RQ11]:** Will administrative services be included [in the research question]?	The research question on public and social services does not include administrative services.
47	IV - Evaluation design	**Page 22. [RQ12]: :** Add expenditures to "energy use"	This has been added.
48	IV - Evaluation design	**Page 22. [RQ12]:** SBEE billing records could also be a data source.	This has been added.
49	IV - Evaluation design	**Page 22. [RQ12]:** Same comment as before: GSI disaggregation is indispensable [for FGDs with households]	We now discuss GSI disaggregation in the two paragraphs preceding this table.
50	V - Grid-level outcomes	**Page 25:** Is Mathematica going out and placing monitors, or are they relying on the distribution design consultant?	We have added text stating that the monitors will be installed by the design consultant.

#	Chapter	Comments	Response
51	V - Grid-level outcomes	**Page 25:** What about commercial losses [in addition to technical losses]?	We do not expect the Electricity Generation and Distribution Projects to reduce commercial losses, which result from theft and poor billing practices. The reform activities that may result in improvements in the commercial loss rate are outside the scope of this evaluation.
52	V - Grid-level outcomes	**Page 26:** It seems to me that one year trend to determine the counterfactual is not adequate for a country subject to huge variations in imports and in its own hydropower production. An analysis of previous 5-7 years to determine the trend would be more appropriate.	Our evaluation focuses on a shorter pre-intervention trend because we are trying to identify intra-week variation, and perhaps seasonal variation, in order to establish a trend. Our ITS design will identify short term changes, but longer term impacts are very difficult to measure, since improvements in one part of the grid will almost certainly impact other parts. The performance evaluation will look at longer term trends that may or may not be attributable to the investment.
53	V - Grid-level outcomes	**Page 26:** [on aggregation and disaggregation across project activities] An additional issue is the sequencing of investments between generation and distribution, both in the past and under the project.	Our ITS approach is designed to allow us to adapt to such changes. As long as we know the timing of the investments and when they come online, we can associate measured changes with the individual activities.
54	V - Grid-level outcomes	**Page 26:** To make sure I have this clear: will you use the different time points when different pieces of infrastructure are commissioned to parse out and then aggregate impacts across the grid? And/or will you try to isolate parts of the grid that are directly affected by the different types of infrastructure?	We will measure multiple separate impact estimates within project areas, so it should be possible to identify the impact of different pieces of infrastructure within the same project area. We will then aggregate these different impacts. We will also separate the network by geographic areas (Natitingu, Parakou, Djougou, Cotonou).
55	V - Grid-level outcomes	**Page 26:** [on ability to asses impacts of each activity separately] If activities are all achieved on schedule, but if not? E.g., can the new generation capacity be immediately delivered when available through the distribution projects to end-users? Or will delays in the latter make the impact of the former not able to be separated.	As long as we are updated on timing of when different improvements to the grid are installed or when increases in generation capacity come online, we will be able to assess impacts of the investment by linking the timing with our high-frequency data.
56	V - Grid-level outcomes	**Page 26:** When you say "area" do you mean "geographic area?"	Yes, this has been clarified in the text.

#	Chapter	Comments	Response
57	V - Grid-level outcomes	**Page 27:** MCC should require that SBEE doesn't remove the monitors, in order to get a better understanding of long-term trends/sustainability (really important).	This point was emphasized during Mathematica's design trip to Benin in September 2017. Mathematica will stay in close contact with SBEE, MCA-Benin, and the design consultant to ensure that the monitors are not removed until they are no longer needed by the evaluation. Once the SCADA system goes online, that system can provide all of the information necessary for the evaluation. After a transition phase in which measurements are compared we would expect the SCADA system to provide the same type of measurements, and SBEE would be free to move the monitors to other parts of the grid. The text has been revised to include some of these points.
58	V - Grid-level outcomes	**Page 27:** This assumption [that users will modify usage behavior given better electricity] should be tested in pre-investment surveys. For some users, e.g., women businesses, additional investment in electricity-intensive equipment may not be made, while more efficient use of existing equipment will. Also note that the tariff policy, such as night/day tariffs, will play a significant role in influencing users' decisions. Again, GSI disaggregation should be documented.	The interim round of data collection will provide early evidence on whether users are modifying their behavior in response to improved electricity service. We have added a sentence about GSI disaggregation.
59	V - Grid-level outcomes	**Page 27:** Private self-supply freeing up grid supplied-electricity for others? Rented and **<u>sold</u>** generators? If grid supply is cheaper than running diesel (likely), # generators out there may need to be reconsidered as means of measuring impact. **Page 27:** [On the statement that rental generation will decrease impact of generation activities but increase the value of distribution activities]. Not necessarily, since the likelihood of unmet/suppressed demand even with MCC investments is high.	We recognize that the text here was not clear on the difference between private generators (those bought by households and businesses for their private use) and rental generators, by which we mean large generators rented by SBEE/GoB to provide electricity via the grid when imports are insufficient. We have revised the text to make it clear that in this section we are referring to large generators rented by SBEE/GoB. With respect to private generators, we plan on measuring electricity consumed from various sources through the household and business surveys. This will include private generators.
60	V - Grid-level outcomes	**Page 27:** [On short-term outcomes] Should look at non-technical losses as well.	We do not expect the Electricity Generation and Distribution projects to affect commercial loss rates; therefore, we have included only technical losses as an outcome.

#	Chapter	Comments	Response
61	V - Grid-level outcomes	**Page 27:** Pre-post and descriptive analysis. The approach seems a little simplistic. How would you account for other non-MCC projects being planned or currently underway? AFD and other European aid agencies have plans of either strengthening the grid or reforming SBEE over the coming years (in addition to MCC's compact). How would the evaluation control for those efforts in the attribution process?	The evaluation as a whole is a mixed-methods evaluation that combines rigorous impact evaluation with quantitative and qualitative performance evaluations. The pre-post and descriptive analyses are part of the performance evaluations. Although they cannot establish causality, they provide useful information where a more rigorous evaluation is not feasible. We will be very clear on the limitations of the different study designs when we present findings.
62	V - Grid-level outcomes	**Page 27:** I have a question on the estimation of the changes in gap between supply and demand as a result of increased generation. How do you differentiate between demand and needs? Where would you draw the line? Many people would like to request connection, but given their geographical position, there is no chance they could get it, and thus have "latent" demand. Those "dormant/latent" demands could be reactivated once there is hope that (with increased generation) one could actually have access. Any risk that such scenarios could affect the findings?	Because we analyze realized demand, capacity, load shedding and outages, we can assess the gap between supply and demand and pinpoint reasons. The scenario described in this comment would result in smaller impacts on the reduced supply/demand gap. However, it would show up in demand growing faster than anticipated given projections that would be an interesting finding in and of itself.
63	V - Grid-level outcomes	**Page 28:** What capacity factor did Cardno Fichtner use and what is used in the ERR model? Just checking for consistency. **Response:** I would have to check but it was around 20% as well.	The ERR used a capacity factor of 20% for the new PV solar plants. We did not find the term "capacity factor" in the Cardno Fichtner reports, but the reports present a panel efficiency of 14-21% for the most common PV technology. Panel efficiency contributes to capacity factor, but they are not the same measures.
64	V - Grid-level outcomes	**Page 28:** Does SBEE already have distribution areas that are defined according to Tx and Dx infrastructure, and not administrative boundaries?	SBEE does not have this type of information, so it would need to be collected through a listing effort. SBEE has however conducted a pilot to link customers to transformers. That pilot will inform our sampling design.
65	V - Grid-level outcomes	**Page 28:** [Regarding census question on the main source of lighting] Not convinced that these data are available.	The INSAE Census questionnaire included a question on the main source of lighting in the household (SBEE electricity, solar energy, petrol, etc.)
66	V - Grid-level outcomes	**Page 28:** Is it part of the work with SBEE to install an MIS that will generate these data? If so, why should the consultant do it?	SBEE has a long-term plan to collect this type of data to link customers to transformers, but they currently do not have this.
67	V - Grid-level outcomes	**Page 29:** How will the consultant be sure of the accuracy of the answers, as people may be 'scared' to admit that they purchase power from illegal connections?	The willingness to pay report recorded over 30 percent of households using secondary connections; this suggests that people are not apprehensive to disclose those connections.

#	Chapter	Comments	Response
68	V - Grid-level outcomes	**Page 29:** [On disaggregating by type of customer] Needs to also have GSI disaggregation, e.g., male-female-youth-other.	Because this is a network-level outcome, it will not be possible to disaggregate by characteristics of the household. However, we do plan to disaggregate by household characteristics such as gender of household head when we estimate impacts on household-level outcomes.
69	V - Grid-level outcomes	**Page 30:** [on systems analysis tools for estimating technical losses]: Such as?	We have revised this section to provide additional detail on when and how we will measure technical losses.
70	V - Grid-level outcomes	**Page 30:** On the demand side, there may be seasonality effects related to major holidays – Ramadan/Eid and Christmas – consumption swings noticeably pronounced around these in nearby countries. (And World Cup soccer!) On the supply side, you have mentioned seasonal impact on hydro flows but Benin not relying very heavily on supply from hydro.	We added holidays as another example of a possible seasonality affect. Seasonal impacts from hydro flows may be relevant since Benin relies on hydropower generated in Togo and Ghana.
71	V - Grid-level outcomes	**Page 31:** On page 31, you note that “Because the grid monitors can in principle provide measurements for every fraction of a second, we will have access to observations from a sufficiently large number of times before and between the introduction of each project activity, and between the introduction of project activities and the time periods beyond their completion.” On pg. 39, however, you remark that “If an outside improvement is switched on very close to the time MCC project activities are taken online, we will not be able to disentangle the two and separately identify the impact of MCC’s investment.” Could you clarify how long of a gap would be necessary between the completion of an MCC project activity and an outside improvement to the grid to disentangle their effects?	The length of time between the implementation of an MCC project improvement and an outside improvement will determine the length of the impact that we can observe. The high frequency of the data that we will collect ensures that it is highly unlikely that another intervention would come online at exactly the same moment. However, if, for example, an outside program came online one week after the MCC investment, we would only be able to rigorously measure one-week impacts of the MCC investment.
72	V - Grid-level outcomes	**Page 32:** So which [grid monitor] option is MPR proposing? How many meters does the project have budget for? Does the energy team want MPR to be able to measure disaggregated impacts? Or is it that we don’t know yet / depends on MCC?	The number of monitors and their placement is currently under discussion. Once a final decision is made, we will submit a memo updating our approach. This has been clarified in the report.
73	V - Grid-level outcomes	**Page 32:** Specify that [the transformer census] is an SBEE census conducted in 2016	We have made revisions to differentiate between the national INSAE census and the SBEE transformer census.

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74	V - Grid-level outcomes	**Page 32:** Statistical Power. I'm not sure how those grid monitors will work, so this question could be irrelevant. Is 10 a good enough sample size with a good enough power for analysis?	Most of the statistical power from the ITS design comes from variation across time. So with 10 grid monitors we can obtain precise estimates for the small number of placements. Where we believe there might be interesting differences across project areas or feeder networks, we have suggested monitoring a greater number of transformers. Running power calculations for 40 monitors and 10 monitors is meant to illustrate the type of questions that could be answered in each scenario. The final number of monitors will be determined through ongoing discussions with the design consultant.
75	V - Grid-level outcomes	**Page 33:** The grid monitors referenced throughout this document are not being installed by Mathematica; the system is being designed and installed by Gopa-Intec, the consultant retained to develop detailed designs for the distribution project. Mathematica needs to make that clear and make certain that what they are proposing is in alignment with what Gopa-Intec is proposing. Presently, there is a significant difference in the number of grid monitors being proposed by Mathematica and what's being proposed by Gopa-intec. Furthermore, this report doesn't seem to make it clear that the grid monitoring system will give way to the NDCC. Mathematica could make it much more clear the risks associated with being reliant on a third party for the grid monitoring system and what they will do to help mitigate these risks. Are they going to actively participate in the final design and installation of the system? Are they going to help QC the data? So far this report makes it sound like it's Mathematica's grid monitoring system, when in fact it is not and our whole evaluation hinges upon this.	The number of monitors and their placement is currently under discussion. Once a final decision is made, we will submit a memo updating our approach. This has been clarified in the report.
76	V - Grid-level outcomes	**Page 35:** See earlier comment about who installing the monitors.	GOPA-Intec, the design consultant, will install the grid monitors. This has been clarified in the report.
77	V - Grid-level outcomes	**Page 35:** Will arrival and infeed monitors be placed on the same sub-stations? Why are there three more for infeed?	As reflected in discussions with GOPA, monitors will be placed on both arrival and infeed monitors at the same sub-station. The number of placements for monitors has been adapted in the memo to reflect conversations with MCA-B, MCC and GOPA. The number of monitors and their placement is currently under discussion. Once a final decision is made, we will submit a memo updating our approach. Table V.2 lists potential number of placements for arrivals and

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			infeeds, but the number of arrivals does not need to match the number of infeeds.
78	V - Grid-level outcomes	**Page 35:** Would there be an equal sample for each customer type according to level of service or would you try to have one type of customer?	We are proposing to stratify our sample of SBEE customers by size and by type of customer to ensure that we have data on households and customers. Household and small business respondents will be stratified by GSI.
79	V - Grid-level outcomes	**Page 35:** Is all of this consistent with GOPA-Intec's Option B Inception Report and their plans? Mathematica will not be placing any of the grid monitors; they need to make sure the Gopa/Intec understand what it intended.	Since the writing of the original draft of this report, Mathematica has met with the GOPA-Intec team on several occasions, including in person during the design trip to Benin. The revisions to this section reflect a plan that has been shared with MCA-Benin, MCC, and GOPA-Intec. We continue to work closely with them as decisions are made.
80	V - Grid-level outcomes	**Page 36:** Pole-mounted transformers. Given the concerns over theft, why Should we pursuit such an option? Any anti-theft mitigation measures to recommend?	We are no longer proposing pole-mounted transformers given the concerns around theft.
81	V - Grid-level outcomes	**Page 38:** Estimating technical losses. Could you propose an estimation formula? The findings seem to fluctuate from reports to reports. SBEE's values are different than those provided by MCC's feasibility consultants 2 years ago. Is this going to continue or will there be a standardized formula to be applied across the board? **Verbal comment from presentation to EMC:** How are you measuring technical losses? Wouldn't you only need SBEE data for that?	We propose investigating technical losses through two means: 1) losses along key upgraded lines and 2) calculating losses based on equipment characteristics and loads at the infeeds as is now starting to be done by SBEE. We have revised this section of the report with updated details on measuring technical losses.
82	V - Grid-level outcomes	**Page 38:** Upgraded rural roads are currently not planned although if there is available funding, could be added back perhaps.	This has been removed.
83	V - Grid-level outcomes	**Page 39:** Please ensure this tracking [of outside investments] is incorporated into the Benin II M&E Plan. MCA is best placed to do this tracking in consultation with MPR, so that they are providing the exact information required for the evaluation. This should be an explicit requirement with a template and agreed-to frequency of reporting.	We will do this tracking of outside investments in consultation with MCA, following what is laid out in the M&E Plan. This has been added to the report text.
84	V - Grid-level outcomes	**Page 40:** The EMC needs to understand this point [that the estimated impacts we would be estimating from the limited set of grid monitors would not be generalizable to all project beneficiaries]	This is noted. We are currently working with GOPA, MCC, MCA-Benin II and SBEE to finalize the placement of monitors and smart meters. Once this has been decided, we will submit a memo updating the design. We will emphasize this risk in the memo.
85	V - Grid-level outcomes	**Page 40**: [On the possible options for installation of smart meters] And investments in IT systems, etc.	GOPA's proposal for smart meter installations includes all required IT systems and data transfer protocols.

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86	V - Grid-level outcomes	**Page 40:** Grid Monitors. Any concerns over maintenance of grid monitors? What is their lifespan in normal circumstances (with maintenance) vs during low-maintenance cases? Would SBEE be able to carry on maintenance costs after the implementation? Any risks of abandonment due to high maintenance costs?	We have relied on the distribution design consultant (GOPA-Intec) to choose the specific grid monitors that will be used and we believe that they will have taken these points into consideration. However, MCA-Benin, the design consultant and SBEE would be better placed to respond directly about the specifics of the monitors.
87	V - Grid-level outcomes	**Page 42:** How do you define small, medium, and large businesses?	Firm size is based on number of employees and follows the categories from the World Bank Enterprise Survey. We added a footnote to the report with this information and the specific firm sizes.
88	V - Grid-level outcomes	**Page 42:** Will the questionnaire allow us to compare time use effects on men vs women within male headed households (in addition to between female and male headed households)?	We are proposing to collect information on time-use for the head, spouse and children, but the level of detail will be determined when the instrument is developed. It is unlikely that we will collect highly detailed time-use data because the costs of carrying out household time use data collections are either infeasible (written diaries) or prohibitively expensive (observation method) and/or we do not want to overburden respondents.

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89	VI - End-user outcomes	**Page 42:** Do you have concerns about the accuracy of household data collected over mobile phones in this context? Do you have examples of household mobile phone data collection in similar contexts? What challenges were faced besides loss of respondents without mobile phone access?	Based on our previous experience with mobile phone survey data collection, we have proposed implementing a very short survey with a limited set of questions, to minimize the burden on the respondent. For instance, a study in Peru and Honduras found that response rates start to noticeably fall for surveys longer than 10 questions (Ballivian et al. 2015). We have also proposed informing the respondent ahead of time about what information we will request. Finally, we will conduct pretesting to determine the prevalence of mobile phone access, signal strength, and familiarity with cell phone use among different population groups. The data collection subcontractor should shoulder the full cost of the call. Finally, we might explore providing a small incentive of phone credit to retain adequate response rates. Dabalen et al. 2016 found that a slight increase in phone credit incentive after round 8 in a longitudinal mobile phone survey in Tanzania led to higher response rates in later rounds of the survey. Recent literature studying the reliablity of different modes of survey adminstration have found surveys administered via mobile phone to produce similar results to surveys administered in-person (Garlick et al. 2017; Ballivian et al. 2015) . A study of microenterprise surveys in South Africa found that respondents were slightly more open in their responses over the phone than in-person, but that in general, responding by phone did not change respondent behavior (Garlick et al. 2017). Citations: Garlick, Robert, Kate Orkin, and Simon Quinn. "Call Me Maybe: Experimental Evidence on Using Mobile Phones to Survey Microenterprises." Working paper, July 2017. Ballivian, A, Azevedo, J P, and Durbin, W. 2015. Using Mobile Phones for High-Frequency Data Collection. In: Toninelli, D, Pinter, R & de Pedraza, P (eds.) Mobile Research Methods: Opportunities and Challenges of Mobile Research Methodologies, Pp. 21–39. London: Ubiquity Press Dabalen, Andrew, Alvin Etang, Johannes Hoogeveen, Elvis Mushi, Youdi Schipper, and Johannes von Engelhardt. 2016. Mobile Phone Panel Surveys in Developing Countries: A Practical Guide for Microdata Collection. Directions in Development. Washington, DC: World Bank

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90	VI - End-user outcomes	**Page 43:** [on measuring monthly firm profits] Assumes business owners would be forthcoming about profits/income changes, and assumes that these are available in a systematic manner.	Accurately measuring profits, particularly for small firms, can be challenging. Because we will measure profits through the mobile phone survey, and therefore are limited in the number of questions we can ask, we will most likely ask firms directly about their profit. There is some evidence to show that a direct question yields more accurate data than asking firms about revenues and expenses (De Mel et al. 2017) Citation: De Mel, Suresh, David J. McKenzie, and Christopher Woodruff. "Measuring Microenterprise Profits: Must we ask how the sausage is made?" 2009. Journal of Development Economics, vol. 88, pp. 19-31.
91	VI - End-user outcomes	**Page 43:** Energy expenditures or overall HH expenditures?	Energy expenditures. We have revised the text for clarity.
92	VI - End-user outcomes	**Page 43:** Have you considered also asking the amount and cost of substitute energy sources? Is it not relevant to ask about other sources of energy? Perhaps the baseline can inform this, but I wonder if we'd want to be able to assess the kind of energy source switching that's occurring, not just the increased consumption of electricity.	We have added the amount and cost of energy consumed from other energy sources as possible outcomes for the ITS analysis.
93	VI - End-user outcomes	**Page 43:** [on weekly hours business is open]: Have you considered asking whether such a change is influenced by better electricity quality?	Since the mobile phone survey in constrained by length, we propose to probe on this question during the qualitative performance evaluation.
94	VI - End-user outcomes	**Page 44:** I think you will need to measure incomes [for households] as well, in order to get at the Program Objective. If not, this should be agreed to explicitly by the EMC.	We have added business income as an outcome in the text. Please see response to comment A5 for a description of why we do not plan to measure household income.
95	VI - End-user outcomes	**Page 44:** The proposed timing for interim and final data collection does not seem to reflect the reality that interventions are likely to not be completed much before the compact end date. In other words, doing an interim survey after 1-3 years of exposure may actually be two years after compact completion, as is suggested for the final data collection.	We have adjusted the wording to make clear that we will space the interim and final data collection at two-year intervals, and adjust the timing in the event that the interventions all happen towards the end of the compact.
96	VI - End-user outcomes	**Page 44:** Need to measure losses of perishable goods	This is noted as a potential outcome measure (destruction of raw materials) in table VI.1

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97	VI - End-user outcomes	**Page 44:** Differentiate between formal and informal businesses? [for business surveys]	We will administer the survey to both formal and informal businesses. This has been clarified in the text. As described in the analysis section, we will conduct subgroup analyses for each group.
98	VI - End-user outcomes	**Page 44:** What about changes in productive use? [for household surveys]	This would be captured through investment in electric appliances and through adult time use.
99	VI - End-user outcomes	**Page 44:** Include energy expenditures in addition to consumption	This has been added to the text.
100	VI - End-user outcomes	**Page 45:** Would [small businesses] include HH that have productive uses?	Yes. We would draw the sample of small businesses from the HH listing. We added this point in two locations in this section for clarity.
101	VI - End-user outcomes	**Page 45:** Are there any quantitative targets for this program that can inform these MDIs?	Based on the discussion during Mathematica's presentation to the EMC, we are not aware of any quantitative targets.
102	VI - End-user outcomes	**Page 45:** [on large MDIs for households] Separately keeping track of those that are newly connected? What about control groups (SMEs and HH never connected before and not connected under project).	We do not propose to collect data from those who are not already connected to the grid. To make this clear, we have revised the text throughout this section to refer to "electrified" households and businesses when appropriate.
103	VI - End-user outcomes	**Page 46:** [On outcome total energy consumption in MDI table] So not interested in the difference in overall energy usage (e.g., candles replaced by lights or solar or battery lanterns)?	In Table VI.2, we present the MDIs for 1-2 sample outcomes. Our full list of outcomes includes overall energy usage.
104	VI - End-user outcomes	**Page 46:** [Regarding the subgroup analyses], what is meant by "type of business," especially considering that sector will be a distinct sub-group.	We have clarified that this refers to whether a business is located within the home or in another location.
105	VI - End-user outcomes	**Page 46:** Should include business manager? [in addition to business owner]	We have added business manager to this section. Our sample will likely comprise both owners and managers, depending on who is available and knowledgeable.
106	VI - End-user outcomes	**Page 46:** How are [vulnerable or poor households] defined?	We will explore a variety of options for defining poor and vulnerable households. We will collect the data needed to create a poverty index using the 2012 Progress out of Poverty Index. Alternatively, we will also search for more recent poverty measures, if available, such as the tool used by the World Bank to implement means-testing for free electricity connections.
107	VI - End-user outcomes	**Page 46:** Need to factor in HHs with productive uses that may not be formal businesses.	Our sample will include both informal and formal businesses operated out of the household.

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108	VI - End-user outcomes	**Page 48:** Differentiate between business owners and managers.	We will try to obtain data from the most knowledgeable person in the business. (See also response to comment A105).
109	VI - End-user outcomes	**Page 48:** HH income is an additional outcome that should be measured (or at least confirmed with the EMC if we are ok not measuring it)	Please see detailed response to comment A5 above.
110	VI - End-user outcomes	**Page 48:** And any substitution of non-electricity sources? [in addition to electricity consumption]	We added "substitute energy consumption" as an outcome in Table VI.3 for households.
111	VI - End-user outcomes	**Page 48:** Should be sure to include - separately - productive uses of electricity in HH.	We added "operation of business outside of the home" as an outcome.
112	VI - End-user outcomes	**Page 48:** If you start the mobile phone survey too early, you risk creating survey fatigue resulting in low response rates when it would matter most.	We would work with MCC/MCA to establish appropriate small incentives to maintain a high response rate. We will also closely work with MCA so that the survey timeline matches the implementation timelines.
113	VI - End-user outcomes	**Page 48:** How will they ensure a valid control group when customers will self select?	The control group are the same households and businesses before the start of the intervention. Any self-selection into the sample will mean that the sample is not representative of the full population, but it will not compromise our ITS estimates.
114	VI - End-user outcomes	**Page 48:** Sampling. Could the evaluation team use MCC's WTP survey respondents to establish a panel sample throughout the exercise? No necessarily use the entire WTP sample size; but instead pull a smaller sample from it??	We plan to sample using the 2013 Benin census enumeration areas or catchment areas served by transformers so that we will have representative data on households and be able to link them with transformers. If it is infeasible to define transformer catchment areas, we will explore using the WTP survey.
115	VI - End-user outcomes	**Page 50:** So rural areas are not covered in the above mentioned 1500 HH and 750 businesses?	We learned during the EDR review process that rural line upgrades are no longer planned. We have removed the referenced paragraph from the text. The sample sizes shown in the table will be drawn from urban areas only.
116	VI - End-user outcomes	**Page 50:** There is no mention here about languages – having to work in multiple local languages for surveys and focus groups. Please factor that into the planning.	We have added to text to this section to include translation into local languages and having data collectors who can administer the surveys in local languages.
117	VI - End-user outcomes	**Page 50:** Mobile phone surveys. Will the program provide cellular phones or credits to respondents? Respondents will be less likely to respond if they are concerned about costs?	We expect that the majority of electrified households in urban areas of Benin will have access to mobile phones, and we will exclude any households that do not. We may consider providing cell phone credit as an incentive to participate in the survey.
118	VI - End-user outcomes	**Page 51:** [On mobile phone ownership] If confined to urban areas, this may be true. In rural, probably not OR only the male has the phone. How will Mathematica handle this?	The sample will be mostly urban, so we expect that nearly all households will have access to mobile phones.

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119	VI - End-user outcomes	**Page 52:** [on the possibility of excluding respondents without a mobile phone] This will undoubtedly skew the results to more advantaged businesses and HH.	We agree that this is a concern and potential risk to the study design. However, we expect mobile phone ownership to be very high among electrified urban households and businesses. Further, because the sample includes only electrified households and businesses, it is already skewed more towards wealthier individuals than the full population. We will learn more about mobile phone ownership during pilot testing, and will be clear about any limitations to the study when we present findings.
120	VI - End-user outcomes	**Page 52:** How will low response rates influence Mathematica's analysis approach? Will it weight strata according to their under- or over- representation in the sample?	Attrition and low response rates can lead to underpowered and biased impact estimates. We will consider statistical approaches to attrition (such as inverse probability weighting based on observable characteristics) if attrition is indeed a large problem. We have updated the text with this information.
121	VII - Optional Study	**Page 53:** The optional impact evaluation of strategies to encourage new connections looks very promising. To improve MCC's ex-ante CBA, we would ideally like to understand 1) whether MCC has used the best possible stated preference survey methodology to measure WTP in this case, and 2) how close WTP as measured through our stated preference surveys is to experimentally derived WTP. Given increased application of the WTP/consumer surplus methodology within MCC CBAs, these questions may be quite important to project selection in practice. Can you briefly discuss how this optional IE might speak to these two questions? For instance, are there opportunities for MPR to test several stated preference survey methodologies against experimentally derived demand estimates?	This question was posed during Mathematica's presentation to the EMC, and we understand that MCC is very interested in testing its WTP methodology. It would be possible to test multiple ways of asking about WTP in one survey, by randomly varying the order in which the questions are asked. This can be explored during the instrument design.
122	VII - Optional Study	**Page 53:** With regard to the Lee et al. study, it appears that credit constraints may be quite important (see Figure 9 from the copy I have below). When a 6 week payment requirement is included in the contingent valuation question, the stated demand is actually similar to the experimentally derived demand curve. The contingent valuation questions that include hypothetical credit offers suggest much higher WTP, although we do not have an experimentally derived demand curve for the with-credit scenario. For this reason, I would encourage inclusion of credit offer treatment arms (if 6 arms are possible).	We understand that MCC is interested in the possibility of a treatment arm that incorporates a credit offer or extends payment for the connection fee over multiple billing cycles. At this time, we have not incorporated that possibility into the evaluation design. We expect that, as details on the 10,000 connection implementation are formalized, we will work with MCC, MCA-Benin, and SBEE to determine the preferred and most feasible treatment arms.

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123	VII - Optional Study	**Page 54. Overall comments on optional study:** I think this is really important, given MCC's past negative experience with uptake. Note that similar distribution improvements and new connections are being done by AFD in Abomey Calavi. Is there an opportunity to also learn from their approach to getting new HHs connected? Consider having Mathematica liaise with AFD project lead (via MCA-Benin II). I think this is really important. Note also that MCC/MCA-Benin II really has not designed this part of the compact; we are waiting on the distribution design work to advance a little further so as to see if we can do the HH connections in places where we are already doing distribution improvements. Therefore, I think there is an opportunity for Mathematica to actively assist MCA-Benin II and MCC in actually designing how we are going to identify HHs for connection and what sort of incentives (or not) we are going to offer for connection. To EMC: We can only take this on if the Energy project leads are interested and willing participants. The first question to answer is whether there is demand for this learning / answering these questions about connection fees and tariffs among the GoB. Has there been any discussion about this in Benin? The second question is around feasibility. Would MCC/MCA be comfortable with connecting fewer customers than 10,000 in order to pay for the connection subsidies (target/optics question)? Is the utility willing to experiment with their connection fee and tariff schedules? Who would manage the experiment? MPR? This would need to be closely aligned with the project work, so are project leads willing to take this on? Does M&E have the budget and bandwidth to take this on? The risks associated with conducting different trials of discounts in particular on the connection fee should be discussed and assessed. For the tariff rebates, at least objective criteria can be used, in particular income levels. In addition, there should be an evaluation of the choice of least cost technical solutions to in-house wiring and low voltage lines. These are well discussed in the Barnes and Galambeanu Paper on connection charges.	We have been monitoring the AFD project in Abomey-Calavi. Although we reached out to the AFD team, we were not able to meet with them during our design trips. We will work with MCA-Benin II to ensure that we stay apprised of their work, and that we communicate our proposed designs to AFD via MCA-Benin II. We are aware that the design of the new connections is not complete. During the latest design trip, we learned: 1. There is uncertainty around where the connections are happening. 2. SBEE has the capacity to implement different tariffs, and also has in the recent past offered different levels of connection fee discounts. The rural extension agency has worked with institutions to extend credit. 3. In order to connect 10,000 households it would be necessary to approach a larger number with the connection offer. It would be prudent to sequence this so as to maximize the chances of arriving at a number around 10,000 connections. 4. AFD has previously provided connections around Abomey-Calavi, but we were not aware that they also were providing them in the current project in Abomey. The proposed design in the report reflects our best understanding at the time of writing. This design can and should be adapted to reflect any final decisions about the funding and rollout of the 10,000 connections. In addition, some policy parameters, such as the feasibility of having subsidized tariffs or tariff rebates, will affect the evaluation design. Most of this design as written in this report reflects our ideal setting for evaluating the new connections using an RCT framework. We will update the evaluation design once the implementation and policy parameters are clearer.

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124	VII - Optional Study	**Page 54:** Project not designed as noted above – [low-income HHs are] not necessarily a target.	We have removed references to low-income households from this section to reflect this new information.
125	VII - Optional Study	**Page 54:** What do they mean by "optional" impact evaluation?	Mathematica has proposed this impact evaluation to MCC as an add-on to the original evaluation. It was not included in the original budget and will only be conducted if MCC and MCA-Benin agree that it is worthwhile. It was not part of the original RFQ
126	VII - Optional Study	**Page 54:** Need to summarize how the methodology [of an RCE] works	We added a brief description of RCE in the footnote on this page.
127	VII - Optional Study	**Page 54:** Isn't the regulator supposed to be involved in the definition of the tariff structure/strategy? **Page 54:** There are multiple references in the document to SBEE changing tariffs – please note that SBEE does not set tariffs and does not have the power to do so. Heretofore, it has been the Government that set tariffs but there is now a regulator in place. Consider that in the design – including consultation with the regulator.	Thank you for highlighting the need to consider the role of the regulator in the evaluation design. During our design trip we learned that SBEE currently provides discounts on both connection fees and electricity tariffs. Thus, it may be an option for SBEE to decide to offer subsidized connection fees or tariffs. We have edited the text for clarity.
128	VII - Optional Study	**Page 54:** Household-level RCT. Given the rapid rate of connections in major cities (especially in Cotonou) are we confident to be able to keep an intact control group throughout the evaluation period? I am worried that by the time the evaluation comes to a close many of the control group respondents would have connections either on their own or through other aid programs.	We understand the proposed 10,000 connections and the related discounts are intended to increase the speed at which households and small businesses in urban areas connect to the grid. If MCC believes that most households and businesses are likely to connect to the grid without any discount or incentive then we may need to reconsider the value of the intervention.
129	VII - Optional Study	**Page 54:** Are non-technical losses same as commercial losses? Our comment indicators guidance only uses "commercial losses". I'm not sure if they mean the same thing	Non-technical losses are the same as commercial losses. Given that commercial losses is the terminology used in MCC documentation, we have revised the report to use commercial losses throughout.
130	VII - Optional Study	**Page 54:** Could MPR propose a budget for the level of work and the methodologies that are being proposed? Should we assume that the initial cost estimates could meet these needs?	Mathematica has included a budget for the proposed optional study with this draft of the EDR.
131	VII - Optional Study	**Page 55**: I realize that the tariff study is part of the PRISP, however, I think that Mathematica needs to take cognizance of whatever comes out of it with respect to connection costs and lifeline tariffs and see if/how that impacts this aspect of the evaluation. To add to what has been mentioned above, there is already (under the current tariff schedule) a lifeline tariff.	We agree that the outcomes of the PRISP have the potential to affect our evaluation. We will request access to the tariff study to inform our designs. Our study would be able to inform SBEE and GoB on the impacts of not just lifeline tariffs, but also on different options of encouraging connections, including discounted connections and/or credit for connections.

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132	VII - Optional Study	**Page 55**: Again, suggest liaising with AFD on their work so as to broaden the opportunity for learning.	This is noted. As described above, we will continue to try to communicate with AFD.
133	VII - Optional Study	**Page 55**: Your discussion on pricing strategies may also include financing options (full payment upfront vs. payment for 1, 3, 5, 10 years).	We added this a potential alternative strategy that could be discussed with MCC, MCA-Benin, and SBEE
134	VII - Optional Study	**Page 55:** Is this [offering multiple levels of discounts] feasible in a situation where all customers must receive similar services? Tricky. Also example situation in TZ where subsidy program had time limits and then stragglers were left out….etc.	We learned from SBEE that they already provide differential connection fees and tariffs (including a lifeline) for the same service. The rural extension agency has experience with managing social tensions that arise and we would interact with them to learn about best practices in the Benin context.
135	VII - Optional Study	**Page 56:** Don't really understand this idea [of trade-off between providing a larger discount to a smaller number of households or a smaller discount to encourage a larger number of households to connect.]	The trade-off assumes that there are limited funds available for discounts. SBEE wants to maximize the number of connections given the resources available, and the discount curve helps to find that optimal allocation.
136	VII - Optional Study	**Page 56:** Why should an evaluation group do this kind of piloting? Isn't it the role of Project I?	We will work with SBEE and the implementing consultant for the 10,000 connections pilot. However, we have rephrased this to suggest that SBEE do this piloting.
137	VII - Optional Study	**Page 56:** What about groups targeted under social inclusion? And female-owned/managed businesses, etc. All targeted discount groups need to be further defined or classified to capture gender-disaggregated impacts and impacts on other groups (youth, handicapped, etc.)	We have added businesses owned by females and low-income households as two other subgroups. However, we will not have the power to detect impacts on smaller subgroups, such as persons with disabilities. Further, our sample does not include youth respondents.
138	VII - Optional Study	**Page 56:** Take into account possible need for regulatory approval to modify tariffs even for a trial.	Once details about funding and designing the 10,000 connections are complete we will revisit this possibility.
139	VII - Optional Study	**Page 57:** South Africa (ESKOM) has (had?) this kind of option [of discounted tariff vs. discounted connection fee]. Result of their experience should be explored.	In a brief search, Mathematica was not able to find relevant information on Eskom's experience. However, we will explore this topic more if planning for the optional study moves forward. We would welcome suggestions for sources that describe ESKOM's experience.
140	VII - Optional Study	**Page 57:** Does SBEE have the capability to implement such an experiment (i.e., in its IT and billing system)?	As noted above, we learned during our design trip that SBEE has already implemented similar discounts to connection fees and tariffs.
141	VII - Optional Study	**Page 57:** [Cluster RCT] Unlikely to work due to inequality of benefits received.	The problem of inequality would be larger with a normal RCT than with a cluster RCT, since individuals receiving different discounts would be less separated. In a cluster RCT, everyone within the same community would receive the same discount, so inequalities would only be evident across communities.

#	Chapter	Comments	Response
142	VII - Optional Study	**Page 57:** The [RD] approach is very research oriented, but may not be totally practical on-the-ground.	This design is feasible if SBEE has a clear needs-based criteria for providing discounted connections. We learned during our design trip that SBEE does not have capacity to means-test; however, a recent World Bank connection study did means-test connection fee discounts, so we believe this would be possible.
143	VII - Optional Study	**Page 57:** I don't understand why the Evaluators would be involved in this work [of deciding a sign-up period length] Also, Six months seems too short a period, especially for new customers. This could be tested with SBEE data on time elapsed between first information on electrification of a neighborhood to the registration of customers.	We have added a sentence indicating that we will work with SBEE to determine the optimal time frame.
144	VII - Optional Study	**Page 58**: prepayment may complicate the comparison [between asking HHs about electricity expenses and using admin data]	We agree that we will have to take this into consideration.
145	VII - Optional Study	**Page 58:** [on timing of benefits] Consider investment in inside wiring even before acquisition of appliances. Also consider that in Benin, there is a body (Contrelec) to ensure safety standards for insider wiring (not certain of their inspection and approval processes and timing therefor).	We have added this as a note in the text.
146	VII - Optional Study	**Page 58**: Timing of the surveys?	This section has been revised to reflect updated plans for a baseline and endline survey, which would occur two years after the end of the Compact. However, we added a note here that the timing is dependent on the actual implementation, and that we may not be able to measure longer-term outcomes if the connections come too late in the compact timeframe.
147	VII - Optional Study	**Page 58:** They should also question the use of electricity (lighting, phone charging, fans, TV, productive uses etc.); the substitution of other sources of energy; and the improvements in living conditions.	The long-term outcomes listed in this section are a few examples of outcomes that we may include. The final list would be determined with MCC prior to the baseline data collection.
148	VII - Optional Study	**Page 58:** Why not estimate the ToT as well?	Estimating the ToT could easily be incorporated into the analysis at the analysis stage if we believe that it would produce valuable findings.
149	VII - Optional Study	**Page 58:** Could you say more about the strategy for estimating spillover effects? Would it make sense to vary the intensity of connection incentives by cluster?	Footnote 19 details our approach to estimating spillovers, which largely follows from Lee et al 2016 (cited in EDR). The feasibility of estimating spillovers by varying intensity of connection incentives depends on details about the implementation, which are still unclear at this stage.
150	VII - Optional Study	**Page 62:** I don't see anything about house/business wiring costs and financing. This is even more important than appliances.	This has been added to the table as an outcome for the mobile phone survey.

#	Chapter	Comments	Response
151	VII - Optional Study	**Page 62:** Question the ability of SBEE to provide adequate, clean data in timely fashion	In general, SBEE has been responsive to our requests thus far. Since the data referred to here are billing data, SBEE should be able to obtain this information in a timely manner. It should particularly quick to obtain data for pre-paid meters (which is what most other donors finance as well) and these meters electronically communicate with a central database.
152	VII - Optional Study	**Page 63:** Are these delays the same as those referred two above (e.g. 4-5 years after the connection)? [regarding timing of data collection rounds]	No, the timing of the baseline and endline survey and the takeup (rapid cycle) survey will depend on the timeline for the connection activity.
153	VII - Optional Study	**Page 63:** This [in the listing and eligibility survey] is where it is important to include GSI criteria and disaggregation.	We have specified in the text that the demographic information will include GSI information. We will work with MCA, MCC, and SBEE to ensure that all relevant questions are included.
154	VII - Optional Study	**Page 63:** Sentence is unclear: "For the outcomes impact evaluation data collection we would sample additional households from the free connection treatment and the full-fee control group as the number of households sampled in these two groups for the rapid cycle mobile phone survey is not large enough to detect impact on socio-economic outcomes." If the mobile phone survey cannot generate socio-economic data, what is the point of conducting them?	The mobile phone survey will collect important interim outcomes, such as electricity use or connection status, which we will ultimately link to socio-economic variables in the face-to-face interviews. A key concern in many projects is take-up rate. For example, we found that the rate of new connections was very low in our evaluation of MCC's investments in Tanzania. The rapid cycle evaluation is meant to inform SBEE about the optimal strategies for connecting customers. The face-to-face interviews are meant to identify the value of connecting. Because the sample requirement for the impact of connecting study is much higher, we only focus on those groups where we expect the largest contrast – the treatment group with free connection and the control group with a full fee connection.
155	VII - Optional Study	**Page 63:** Role of distribution design consultant in this [the cluster RCT] as well.	We do not anticipate a role for the distribution design consultant in designing the cluster RCT. If there is a role for the design consultant in identifying where the 10,000 connections will occur, we will be sure to work with them.
156	VII - Optional Study	**Page 63:** Confusing: 10K connections or 10K connections for poor? If latter, then # of connections could be a lot more than 10K	We have revised this chapter to clarify that the connections may not be for low-income households.
157	VII - Optional Study	**Page 64:** Avoid this [outgoing secondary connections] by offering free or financed connx to all in an area.	Even with changes to the design, we don't believe we will be able to control whether households or businesses use secondary connections. However, It will be useful to learn about the extent of secondary connections and how they change in the intervention areas, since secondary connections appear to be common in Benin.

#	Chapter	Comments	Response
158	VII - Optional Study	**Page 64:** Secondary connections are visually evident all over Benin and SBEE customers speak very freely about their “retail” activities.	Thank you for this information; we have added a similar statement to the text.
159	VII - Optional Study	**Page 64: It** would be interesting to see what the administrative data show in terms of % of customers with IDs which provide a cell phone reference.	We appreciate this suggestion, which we will explore once we have this data.
160	VII - Optional Study	**Page 65:** Could some of the households already be connected, and without the discount? [regarding risk of noncompliance - HHs in the control group receiving discounts]	As we do not yet know in which areas the project is likely to provide connections, we cannot answer this question. This is certainly an issue to keep in mind.
161	VII - Optional Study	**Page 65:** [Stating that a third of connections are secondary connections] contradicts the lack of information on this stated above.	We revised our wording above to clarify that we don't know details about where secondary connections are found, but that we do understand that the secondary connection rate is fairly high.
162	VII - Optional Study	**Page 65:** Or benefit from street lighting (cluster of children studying under lampposts) [in addition to benefits from a neighbor having outside lighting]	Yes, we agree that this is a spillover effect from a community connection to electricity.
163	VII - Optional Study	**Page 65:** I would suggest that they build a model on the timing of new connections and evaluation to test whether there will be time to generate sufficient data, or whether the contract should go beyond the Compact implementation period. **Page 65:** Timing issues….. [with regards to challenge: If SBEE provides the low-cost connections only during the final year of the evaluation]	We agree with these comments, but do not have enough information at this stage to make a concrete plan. These are issues that we will address as we move forward with the design.
164	VIII - Qualitative	**Page 68:** Some thoughts [on measuring implementation with qual data during interim data collection]: Would periodic check-ins on the infrastructure by your engineer be useful? Perhaps they could do an annual implementation review, with a standard observation checklist and questionnaire. At a minimum, MPR should inspect the infrastructure built at one or both of the post-construction rounds of data collection to provide context for results (i.e. if equipment is in poor shape/ non-operational). I wonder if a more structured approach to implementation fidelity (with specific aspects of implementation that we’re trying to learn about) would be beneficial for the rest of the evaluation. Maybe this would need to be designed mid-compact, but we want to make sure that the implementation study is not an afterthought (it’s clear that you’re not planning for it to be, but we haven’t seen very structured implementation studies so far).	Thank you for this suggestion. We will budget for a structured observation plan by our engineer with details to be determined as the implementation plan is finalized in coming months. Please note that this structured observation would not rise to a level of intensity/formality as the role of the oversight engineer. However, we agree that the implementation analysis is a key component of the evaluation as it will help us to understand the results from the quantitative analyses.

#	Chapter	Comments	Response
		Page 68: Again, I suggest observations of infrastructure as well as KIIs/FGDs	
165	VIII - Qualitative	**Page 68:** Define "urbanicity"	We revised this to "urban/rural status"
166	VIII - Qualitative	**Page 71:** [with regards to data sources] Other MCA-Benin staff may be of interest as well…National Coordinator, GSI expert, ESP expert… There will likely be a post-compact entity, possibly comprised of some MCA-Benin staff.	We have revised the table to reflect this comment.
167	VIII - Qualitative	**Page 71:** I'm on the fence about doing the following qualitative data collection unless it's sequenced with the quant. If it's done at the same time, I'm not sure how much more it would add to a detailed HH/business survey.	We will sequence the qualitative and quantitative data collections so that they build on one another. Typically, we would do some qualitative data collection to prepare the quantitative surveys but the main qualitative data collection would build on and be designed after we have done preliminary analysis of our quantitative results.
168	VIII - Qualitative	**Page 72:** Does "expectations for benefits of improved electricity" cover those that switched from other electricity source to SBEE as result of project? Assumes no first connectors in group?	Our evaluation is only considering those who are already connected to the grid. We have clarified this in the text.
169	VIII - Qualitative	**Page 73:** [To project monitor] – see if your team can do some research about potential data collection firms. It would be ideal if they could find a set of firms that could handle both [qualitative and quantitative data collection].	We have noted this comment, which does not require any changes or edits
170	VIII - Qualitative	**Page 74:** [regarding the coding scheme]: Can you pre-specify some of these codes to guide the interview guides?	We will develop an initial code frame that maps to the research questions and salient categories of respondents. Code development will proceed iteratively as we review and analyze the data.
171	VIII - Qualitative	**Page 74:** [regarding the challenge of measuring longitudinal perspectives if project areas change]: This point should be emphasized for the project team, so they understand how project design changes affect our ability to measure results. i.e. M&E must be involved in project design or implementation plan changes.	We have noted this comment, which does not require any changes or edits
172	IX - Admin	**Page 76:** Do we know for sure whether Benin requires a local research approval? This should be stated one way or the other here.	We understand that Benin requires local research approval from the statistical committee. We have added text to this paragraph about the requirement.

#	Chapter	Comments	Response
173	IX - Admin	**Page 77:** Please bear in mind that the plan was to install the data loggers to collect certain M&E information and then when the national dispatch center is completed switch over some of that data collection to the NDCC at which point SBEE would be free to use the data loggers however they wanted (including moving them elsewhere in their system).	It is our understanding that the SCADA system will replace almost all grid monitors except at generation points. We will work with SBEE to ensure that the grid monitors are not moved until we can obtain the same data from the SCADA system.
174		**Annex A (page 89):** See earlier comments about the project activities.	
B. Comments from NRECA/Energia			
1		**General. NRECA/Energia: 1. Clear definitions and consistency of references throughout are needed for key constituencies targeted in research questions.** It would greatly help to have the GSI target groups for Benin clearly specified early in the document, along with references to the sources of those targets: i.e., the MCC GSI policy and the recently completed SGIP for Benin. As is, the reader finds most of the GSI target groups are included in a scattered manner in the proposed evaluation plan, making it hard to know who is included. It would also help to clearly define terms used, such as “social inclusion” and “sustainability.” Thereafter, it would be quite helpful if the plan would consistently refer to the target groups using consistent references. An introductory explanation of terms and affirmation that all the TOR-targeted groups will be included would help eliminate any confusion. Vague references to social differences and social variables should be sharpened up and made consistent throughout. Social services seem to be forgotten until, fairly late in the plan, they surface as a target. Ethnicity and social differences are cited in the TOR for the assignment, but virtually ignored in the evaluation plan. In addition, the plan often refers to “energy,” which is ambiguous when referring to, for example, household expenditures and substitutions. Please clarify wherever possible whether the evaluation is asking about electricity use or cost or the HH or businesses’ total energy costs, which may include wood, kerosene, candles, batteries, diesel, etc. as well as electricity.	Mathematica appreciates this thoughtful input from the GSI team. In the Evaluation Design Chapter (chapter IV), we included a short section that summarizes the evaluation's approach to GSI considerations. In this section, we have explicitly referred to the groups that the evaluation will consider, and we defined social inclusion. It should be noted that at the time of writing, we did not have access to the SGIP referenced in these comments, so our understanding of the GSI components of the compact comes from the compact itself and the RFP for the evaluation work. We will review these documents and incorporate our findings into our data collection plans. We have also reviewed the entire document to ensure consistency and clarity in our references to energy and electricity. Finally, we acknowledge that social services are not a main focus of the early part of this report. They are mentioned in Table IV.2, research question 11. However, because we can only evaluate benefits for these organizations through qualitative work, we do not discuss this research question in detail until Chapter VIII, Qualitative Analysis.

#	Chapter	Comments	Response
2		**NRECA/Energia: 2. Meeting the needs of the GSI component of the Compact.** The GSI component of the Compact focuses on improving women entrepreneurs' business operations and expansions through elimination of key barriers to their social and economic advancement. One of these barriers is access to safe, affordable, reliable electricity supply. It is vitally important that efforts be made to have the evaluation focus specifically on whether electrification improvements made any difference for female entrepreneurs vis-à-vis their mainstream male counterparts. The evaluation approach should be able to identify the effects of improved electricity supply and access to grid electricity by households (HHs) and businesses, and distinguish factors that motivated: their connection to the grid; purchase of labor-saving devices; business expansion, etc., as well as identifying the factors that hindered those connections, purchases and expansions, all differentiated by gender and mainstream vs. targeted (socially excluded or marginalized) groups. This is an ambitious plan, but it may still be inadequate to support the needs of the GSI component. While the research plan is comprehensive, the issue of sufficiency of the sample sizes needed to be statistically valid is paramount. Other related points are: • I am concerned that some of the tools (mobile phone survey) for information gathering, and the expectations for especially the poor (uneducated) or marginalized groups to be able to answer the questions may not produce the anticipated data results. Thus it is suggested that Mathematica try to refine down or simplify its questions for these populations and to use local intermediaries (NGOs, churches, etc.) to help collect information from (GSI-relevant) stakeholders. • It is also unsure to what extent SBEE data would be used, why SBEE isn't being charged with assuming responsibility for collecting and managing data on its customers. At any rate, it is recommended that MCC request SBEE to cooperate fully with Mathematica's data needs, insofar as it is able. The planned quantitative data analysis described in the report risks	As noted above, we have included a short introductory section in Chapter IV that summarizes our approach to GSI. In that section, we acknowledge the focus on female entrepreneurs, emphasizing that we will include gender disaggregation and ensure that our sample includes female business owners and managers. We also explain that the qualitative analysis will focus on understand the channels through which different social groups experience the projects' benefits. Finally, we state that our sample sizes for the quantitative analyses were chosen to allow for disaggregation. We will focus on gender and income as our primary subgroups to avoid having analyses that are too fractionated. Although Mathematica intends to work closely with SBEE to obtain relevant data, we do not expect SBEE to be able to provide detailed demographic information on its customers that would be needed for the subgroup analyses that are planned. It should be kept in mind that the main components of the evaluation (the optional connection study excepted) focus on households and businesses that are already connected to grid electricity (whether through a primary or secondary connection). Mobile phone penetration is 85% in Benin as a whole and we would expect that this would be even higher among urban, electrified households.

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		being too fractionated and therefore will probably fail to adequately identify the differences in motivating or dissuading factors over time. It is possible that the planned focus group discussions and in situ meetings with target groups would overcome this shortcoming. Mathematica should consider asking a series of questions to get at (and cross-check) motivational factors and the relative importance of electricity (connection or improved quality) to the HH or business owner with disaggregation by gender. Other GSI groups (e.g., poor, youth, handicapped) should be identified, tracked and measured as such as far as possible, too. It should be noted and factored into the evaluation how households with productive uses of electricity may be evaluated, as the impact of access may be significant to household income, etc., even though it may not be included among the “business” group.	
3		**NRECA/Energia: 3. The need for low-cost technical solutions for connections.** It is well known that inadequate internal wiring and the cost to upgrade wiring to standards can insert a significant barrier to obtaining a connection if SBEE (national) standards must be applied. The proposed Mathematica evaluation plan should explicitly include this barrier, as appropriate, in its probing of HH and businesses on reasons for not connecting or delaying connection. Note: It is not clear whether the connection component of the project is considering technical solutions to reduce the cost of new connections for low-income consumers or whether the evaluation plan takes into account that cost factors for connections may include meeting code requirements for safe use of electricity – and that these may be prohibitive for many HH and small businesses. In other countries such as Kenya, Liberia and South Africa, electrification projects introduced least-cost solutions such as “ready boards” for simple structures to reduce the cost of upgrading internal wiring and meeting safety requirements that might be imposed as a condition for obtaining a connection. This issue would be especially important if existing informal, but sanctioned, secondary systems are going to be upgraded to become SBEE’s formal distribution system standards.	Thank you for this pertinent feedback on internal wiring and the challenges it entails. We have added barriers to connection and the cost of internal wiring as outcomes listed in Chapter VII for the optional connection study. At the time of this writing, the design of the 10,000 connection component of the compact had not been determined. This report reflects our current knowledge of the design, but we look forward to seeing what the final design incorporates.

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4		**NRECA/Energia: 4. Impact of distribution investment costs on affordability of consumption (tariffs).** Will the Mathematica evaluation include estimation of the impact of investment costs on end-user tariffs and therefore on affordability of consumption for different GSI and low income segments? This is an important adjunct to the discussion and planned evaluation of how tariff adjustments might be made to improve affordability of consumption. The plan acknowledges that links to policy interventions will be challenging to include in the evaluation. To avoid this challenge pro-actively, MCC may discuss options with Mathematica?	We agree that the tariff adjustments are a very important component of the compact. However, Mathematica is not responsible for the evaluation of the Policy Reform and Institutional Strengthening Project.
5		**NRECA/Energia: 5. Impact on GSI target groups of legalizing illegal connections: winners and losers.** The evaluation plan fails to mention the concern that there might be negative GSI impacts from the Compact's actions (i.e., status quo connections, albeit illegal, may be more affordable than those that will be provided through the electrification project). Will this be included in the analysis and, if so, how?	Mathematica will measure whether households are connected to the grid via primary or secondary connections; however, we don't think there is any aspect of the Electricity Generation or Distribution Projects that would require households connected via a secondary connection to switch to a primary connection.
6		**NRECA/Energia: 6. Adequacy of survey methods to reach full range of constituencies.** Will survey methods suggested (especially mobile phone surveys) adequately capture the full range of the constituency, especially those without easy access to mobile phones or unable to adequately answer complicated questions to be asked? Adequate compensatory cross-checks for these likely gaps will be needed to eliminate skewing the results.	We will pretest all of our instruments to make sure that the questions are simply and easily understood by the respondent. Enumerators will be fluent in local languages, and we will train the enumerators in ways to ensure that respondents have understood the question. The piloting will also help us to understand mobile phone ownership and response rates. Because mobile phone ownership rates are reportedly very high in Benin, and because our sample will be in urban areas, we do not expect that a large proportion of the population will be excluded. However, this is a risk of the study design.
7		**NRECA/Energia: 7. Clarifying, separating and reducing the nested set of uncertainties.** The proposed approach and methodology is comprehensive, but extremely complicated due to the nested set of uncertainties that remain to be decided prior to adopting the final evaluation methodology. Some uncertainties include the number of connections to be done (so far just a round number: 10,000), the actual areas selected to be connected, and the areas that would be	Mathematica agrees that there remain a number of critical uncertainties with regards to the design of the 10,000 connection component of the compact. If MCC and MCA-Benin decide to go ahead with the proposed optional connection study, Mathematica will work with all relevant parties to revise the evaluation design based on final implementation plans. The main components of the evaluation (Chapters V and VI) focus on households and businesses that are already connected to the

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		equipped with monitoring. • Does the evaluation plan adequately plan for the time and effort needed for the range of stakeholders to make their respective decisions on different issues in order to have a certain set of evaluation tasks and questions to be answered in the time allotted? • What is the balance (weight) of the evaluation effort between those with existing connections and those that are first-time connections?	grid. The optional connection study would focus on households that are not yet connected.
8		**NRECA/Energia: 8. Experiments on discounts of connection fees and tariff options.** The inclusion of “experiments” to determine how deep a “discount” to give on either connection fees and/or tariffs in order to fine-tune the balance between willingness to connect with need for revenues is an admirable goal. Doing the experiments and evaluating them would contribute greatly to understanding the trade-offs that occur when trying to maximize “quality” connections while providing access to all. However, the experiments add numerous dimensions of complexity. Finding a way to give differential benefits to different groups is always tricky (as noted) even if a “fair” or unbiased method (i.e., a lottery) is used. The feasibility of doing this without unrest or dissatisfaction of those who do not get the benefit should be seriously considered prior to detailed design and launch. The income eligibility approach that is also mentioned may be more acceptable and easier to implement fairly and without controversy. Mathematica should plan adequate time and interactive sessions with the range of stakeholders to determine the efficacy of conducting such experiments. Also, it is unclear why the regulator wouldn’t assume responsibility for the socio-economic studies to determine subsidies (discounts), rather than the project evaluation team?	Mathematica strongly agrees that it will be important to have interactive sessions with a range of stakeholders when determining the discounts or incentives to be offered. We have already had initial conversations with SBEE about the challenges of providing different subsidies within and across communities. Mathematica will also work with the independent regulator to ensure that the study produces valuable learning for them.
9		**NRECA/Energia: 9. Period of evaluation.** The periods for undertaking evaluation (6 months, 1 year) after interventions seem too short to be able to capture notable changes/trends.	We will collect data on medium and longer-term outcomes in a final data collection round that will occur after the end of the compact. This will be part of the performance evaluation, so we will not able to causally attribute results to the projects. Ideally, this data collection round would occur 3-5 years after exposure to the interventions. However, if the projects are not completed until the end of the compact, we will only be able to measure outcomes about 2 years after implementation.

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10		**NRECA/Energia: 10. Failure to include commercial losses in evaluation.** The discussion of technical losses is well developed in the evaluation design, but the need to include commercial losses (theft, graft and ineptness) as well as an evaluation factor should not be dismissed. Lower tariffs to stimulate the economy and the financial health of SBEE depend on reduction of its significant commercial losses. Even if the "reform project" is tasked with dealing with reduction of commercial losses, the impact of these losses (e.g., graft may require supplemental payments to corrupt employees for services already paid for which, in turn, reduces the likelihood of connection by those who cannot afford or will not accept paying the bribe). This is an important area to probe with existing and potential customers.	As discussed in earlier responses, we do not plan to measure commercial losses because there is no direct link between the Electricity Generation and Distribution Projects and commercial losses. However, we could consider including questions about billing and theft in the qualitative study to better understand the scope of these problems and their effect on customer decision-making.
11		**NRECA/Energia: 11. Other beneficiary level impacts.** The evaluation should test the change in HH expenses/unit of consumption and/or total electricity expenses as a share of disposable income. It should also consider using change in household income of itself as a factor to evaluate the benefits of access to grid electricity, which may be significant in the case of productive uses of electricity in the household. For businesses, these questions are better informed later in the document, in terms of the impact on the profit/bottom line of businesses. The evaluation should also include probing the benefit to beneficiaries of public lighting for safety and security.	It can be challenging and time-consuming to obtain reliable estimates on household income. As discussed in response to comment A5, it is not clear that there is a direct link between more reliable electricity and meaningful changes in income. Since we need to be conscious of demands on respondents' time, we are not sure that it is worth including income as a measure. The effect of improved lighting on public safety is something that we could explore through our qualitative work. Table VIII.1 provides examples for key areas of focus, which can be expanded or changed as the FGD instruments are developed.
12		**NRECA/Energia: 12. Additions to the Literature Review needed.** On page 16 of Mathematica's document, items # 2 and 5 could be supplemented by the NRECA-ENERGIA Benin Mission 1 Report, Mission 2 Report, and Report of Findings (all 2016) for MCC, regarding the views of business women and groups in Benin. In C1.17: Mathematica reports the lack of documentation on the switch from kerosene to electricity. For lighting, there are many	Thank you for these suggestions. We have reviewed the documents and will use the findings from the mission report as we develop our instruments. However, we have not revised the literature review at this time.

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		references. They can also find some Benin references in the above-mentioned 2016 NRECA-ENERGIA Benin Mission reports. Additional references that are recommended include the ESMAP studies for Bangladesh and Peru, and the Barnes/Golumbeanu 2013 Study on connection charges (World Bank Research Paper 6511).	
C. Comments from local stakeholders during design trip, September 2017			
1		"Au sujet des réalisations il estime que en segmentant seulement sur les zones d'intervention de MCC que nous pouvons mieux isoler les effets." (Someone noted that we might be able to better isolate the effects of the interventions by segmenting across MCC zones of intervention).	This comment is in line with our current approach to collecting quantitative data. We are only proposing data collection in places where MCC is funding improvements to the distribution network or where MCC is funding increased generation capacity.
2		"Qualite de l'energie aupres de la clientelle Lutilisation des compteurs intelligents et si ils ont une idee des déjà des compteurs" (The person in charge of post-consumer energy quality: do you already have an idea of how the smart meters will be used?"	Please see the revised Chapter V for a description of how the smart meters will be incorporated into the evaluation.
3		"La clarification sur le projet distribution il n'y a qu'un seul projet de production photovoltaique" (He clarified that there is only one photovoltaic energy project)	Our understanding from the project development documents is that the Photovoltaic Energy project is planning 3 PV plants in Bohicon, Parakou and Natitingou, though some of these may be through IPPs.
4		"La deuxieme clarification cest un dispaching de distribution alors que le dispaching national pas besoin distribution management software." (His second clarification is that there is no need for national distribution management software)	This is an implementation issue, which is outside the scope of the evaluation design report.
5		"Comment se fera l'etude sur l'affectation de temps ou on ne tient pas un calendrier" (How will we study the time allocation where we do not have a calendar?)	We will develop an instrument to measure time use for children and adults as part of the quantitative and qualitative data collection. We anticipate only asking about the past week or the past day, because we do not want to overburden the respondents. For this reason, we will not use more detailed instruments, such as asking respondents to track their own time-use with a journal We will use focus group discussions to provide more detail on the time-use findings we observe in the household surveys.
6		"Directeur des Etudes demande si L'impact du projet sur la SBEE même sera-t-il evaluer" (The director of studies asked if the impact of the project on SBEE itself will be evaluated)	We will estimate measures that reflect the quality of services provided by SBEE, such as technical losses in some parts of the grid. Our qualitative data collection will also collect information on customer satisfaction and SBEE maintenance practices. However, it is the Policy Reform and Institutional Strengthening

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			Project that is expected to have substantive impacts on SBEE as an organization.
8		"La tendance peut être a la hausse compte tenu des effets utilises, ou il a été senti que la demande accroit compte tenu des besoins comment cela se fera pour avoir la situation réelle." (The trend [in electricity use?] may be upwards in light of the intervention effect, or it may be because demand is increasing--considering demand will be necessary to get at the actual situation)	The estimation of the short-term effect of upgrades on the supply-demand gap accounts for pre-intervention trends through the ITS design. If demand is steadily increasing in the period before the intervention, the counterfactual trend estimated with the ITS will also be increasing.
9		"GOPA a évoqué que il y aura des analyseurs de réseau à mettre sur la moyenne tension, il y a des fonctionnalités des compteurs intelligents, de segmenter la consommation par différentes période de temps." (GOPA mentioned that there will be network monitors placed on medium voltage lines, which will have smart meter features such as segmenting consumption by time period)	We have noted this comment, which does not require any changes or edits
10		"La détection des coupures, les débuts et fin, fixation des seuils de la tension, adapte à la basse tension et aux besoins de l'étude. On peut renvoyer ces informations sur des plateformes de collectes avec des couches de logiciels de gestion des données différents" (The detection of outages, startings and endings, and settings of voltage thresholds will adapt to low voltage lines and study needs. This data can be returned to the collection platforms with different layers of data management software)	We have noted this comment, which does not require any changes or edits
11		"La dissociation des couts, la facturation, les aspects financiers sont à prendre en compte." (The separation of costs, invoicing, and financial aspects must be taken into account).	We have noted this comment, which does not require any changes or edits
12		"Sur les questions de l'inclusion sociale comment les bénéficiaires font usage de ces branchement, combien ne payent pas quelle est la durabilité de cette intervention et continue d'utiliser le réseau." (On the social inclusion aspects: how do the beneficiaries take advantage of these connections, how many take advantage of the reduced tariffs, and what is the sustainability of this intervention in keeping beneficiaries connected to the network?)	These are important questions that would be answered in part through the rapid cycle evaluation (do they take advantage of reduced tariffs, how does it vary by tariff rate). During the final data collection round we would collect information on whether the household was still connected to the grid.
13		"La prise en compte des impacts environmentaux" et "quelle est la demarche a utiliser pour apprecier ces aspects" (how will the study take environmental impacts into account and what is the approach used to take these impacts into account?)	This is outside the scope of our work and is not included as part of the design
14		"Il a aborde cet aspects aussi, si elles sont lies au cadre logique on intègrerait cela directement. Mais si ce sont des questions lies a la détermination des dédommagements." (He addressed this aspect [environmental impacts] too--if linked to the logical framework, we	An environmental assessment or assessment of resettlement is beyond the scope of our work. Through focus group discussions, we can learn about the extent of environmental changes resulting from the investments, or any implementation delays due to

#	Chapter	Comments	Response
		would integrate environmental aspects directly, but if they are questions related to the determination of compensation)	environmental factors, but this would not be a major focus of the FGDs.
15		"[Au sujet de] L'enquête trimestrielle par téléphone: A t'il été déjà utiliser / quels sont les défis à lever pour optimiser la mise en œuvre de ces soucis afin qu'arriver il n'y ai pas de perte/" (With regards to the quarterly telephone survey, has it already been used/what are the challenges to optimise its implementation so there are no data losses)	In the report, we have outlined the risks to mobile phone survey data collection and our proposed approaches to mitigating those risks. We have also included responses to similar comments on mobile phone survey data collection earlier in this document.
16		L'évaluation de la SBEE selon MCC sera fait autrement avec les reformes. (According to MCC, the evaluation of SBEE will be done separately as part of the reform evaluation)	We agree with this comment, as also highlighted in our response to comment C6.
D. Comments from MCC, second round, February 2018			
1	Section II, A	**Page 5, Footnote 3:** Minor clarification regarding the procurement that has been launched in connection with IPPs – the open procurement was not to commence the IPP project itself but rather to hire the consultant to develop the IPP framework for Benin and to then serve as the transaction advisor to structure and lead the solicitation for an IPP developer to construct the solar PVs.	The footnote has been revised to reflect these clarifications.
2	Section II, A, Electricity Generation Project	**Page 5:** With regards to project preparation for the solar PVs, the current intention is for MCA to acquire the sites, secure permits, and prepare the environmental and social impact assessment. Depending on the nature of the recommended mitigation, either MCA or the contractor or the IPP will address the risks.	The text has been revised to reflect these clarifications.
3	Section II, A, last paragraph	**Page 7:** When the decision was made by MCC (pursuant to IMC meeting) to accommodate the GoB request for a management contract for SBEE, the funding that had originally been planned for maintenance management was redirected to support the management contract. What (and how much) will be done to support maintenance management now is uncertain.	The sentence referring to SBEE's maintenance obligations has been removed, as it is uncertain whether this will be required.
4	Section IV, A, Table IV.1	**Page 21:** For RQ1.a., it seems that it would be important to understand not only what changes were made to the design but why changes were made. (E.g., changes have already been made at the request of the GoB.)	We have revised this research question where it appears in Tables IV.1 and IV.2 to include a question of *why* changes have been made.
5	Section VI.D, Table VI.3	**Page 49:** Why the much lower sample size for the medium and long term impacts as compared to the sample size for the short term outcomes?	We added a note below this table in the report explaining that because very precise estimates are not necessary for the pre-post analysis, can we draw a smaller sample for the medium and long-term outcomes.

#	Chapter	Comments	Response
6	Section VII.D, Table VII.1	**Page 60:** The use of the term “implementing agencies” is not clear in the context – do they mean implementing entities in MCC parlance or do they mean implementers as in contractors and consultants who construct or produce other types of deliverables? Need for clarity. See also page 62 where implementers is used.	We have clarified the text in the two referenced locations. "Implementing organizations" refers to the organizations that are contracted to design and construct the planned infrastructure or to produce other project-related deliverables.
7	Section VIII.E	**Page 67**: re timeline. The Benin II compact entered into force in June 2017 and will thus end in June 2022. There are many compact where the works have been completed at the very end of the compact. Although we hope the same does not happen in Benin, we have to be realistic -- the proposed dates of 2023-2024 for final survey and qualitative data collection seem too soon after the compact end date. Reconsider the base plan which will, as is indicated in the text, will have to be reconsidered as the implementation timeline evolves.	Because the compact implementation plans are fluid, we have not revised our proposed data collection plans or the timeline figure as it appears in the report. However, we understand that the dates of data collection are likely to change, and we will be in regular communication with MCC about the optimal timing.
8	Appendix A, A.1	**Page 82:** Household RCT -- It would be Interesting to test impacts of the use of post-paid and prepayment meters on customer retention once connected and on the amounts of electricity consumed and on overall collection rates. Rather than only testing various levels of discounts for connection, it would be more interesting perhaps to test various payment mechanisms for the connection charge – spread over time (as cost of purchasing a cell phone in many places), etc. The approach, focusing on connection costs, overlooks other front end costs – of inside wiring, purchases of appliances that will use electricity, etc.	Thank you for these comments - we agree that what is proposed would be very interesting. We will include these ideas as part of our ongoing discussion with MCC and MCA-Benin about interest in and design of the RCT. However, we have not made any changes to the text at this time.
9	Appendix A, A.1	The proposed methodology of testing various levels of discount for connection fees and/or customer tariffs (even below the lifeline rate) presumes an ability on the part of the utility to subsidize new customers. What is the incentive of the utility to do so when such customers, even on the lifeline rate, do not cover their cost of service and may lead to increasing financial losses for the utility? Have other directed forms of subsidy been considered?	