Essays on the attitudes, behavior, and decision-making of income-constrained electricity consumers:

Implications for integrative grid and off-grid business model planning

by

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Abstract

Electrification rates in a number of low income and developing countries have faced steady improvements in the last few decades, with impressive technological advancements in both the grid and off-grid sectors. There are nonetheless vast swaths of the planet – largely concentrated in India and sub-Saharan Africa – that continue to face troublesome gaps, along both extensive and intensive margins, in progress toward the goal of universal electricity access by 2030. In spite of widespread technical developments, growth of digital platforms for stakeholder engagement, and improvements in technocratic optimization tools for planning, stubborn challenges remain in the distribution sector of LIDCs, placing persistent constraints on equitable growth, private investment, and development for the 1.6 billion rural citizens living in the dark during an era of rapid urbanization. Attaching particular focus to India, which houses 300 million of the global energy poor, this thesis will argue that inadequate attention to consumer attitudes, behavior, and decision-making patterns perpetuates gridlocks in surpassing the final frontiers of global electrification. This overarching argument will be developed over a series of standalone, yet intellectually connected essays that derive from a mixture of applied political economy methods: first, an in-depth context analysis of electricity distribution in India will be introduced. The second essay extends beyond the Indian context and is largely organized as a state-of-knowledge paper that examines the complex relationship between ability-to-pay, willingness-to-pay, and welfare, and the ways in which nuanced socioeconomic, behavioral, and technical dynamics endogenously interact with these variables. In doing so, several hypotheses and case study analyses will be presented and deficiencies in this nascent literature which merit more academic engagement will be highlighted. The ultimate paper will conclude by offering different sets of consumer engagement and behavioral design recommendations that can advance an integrative approach to grid and off-grid business model planning. In holistically examining the complex nexus between electricity access and the consumer psyche, this thesis aims to provide deeper insights into the lives of the energy poor and advance a human-centered design approach to electrification planning in developing contexts.

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There is a proverb from the Haya ethnic and linguistic group based in northwestern Tanzania that translates to *many hands make light work.* The meaning behind this saying will become abundantly clear throughout the remainder of this thesis on electricity access in low income settings. Yet, here, I want to give attention and gratitude to the people – the *many hands* - who have, throughout this two-year journey at MIT, given me light in times of darkness, made the bright times ever more illuminated, and imbued my experience with intellectual enlightenment and growth.

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Abbreviations

AREP	Accelerated Rural Electrification Programme
ATP	Ability-to-Pay
BERC	Bihar Electricity Regulatory Commission
BPL	Below Poverty Line
CEA	Central Electricity Authority
CNSE	Cost of Non-Served Energy
DDUGJY	Deendayal Upadhyaya Gram Jyoti Yojana
DISCOM	Distribution Company
E-Act	Electricity Act of 2003
ESMI	Electricity Supply Monitoring Initiative
GARV	Grameen Vidyutikaran
HH	Household
kWh	Kilowatt-Hour
LCOE	Least Cost of Electrification
LIDC	Low-Income and Developing Countries
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MIDC	Middle-Income and Developing Countries
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MTF	Multi-Tier Framework
OGDGBFS	Off-Grid Distributed Generation Based Franchisee
PAHAL	Pratyaksh Hanstantrit Labh
PAYG	Pay-as-you-Go

PPP	Public-Private Partnership
REC	Rural Electrification Corporation
REM	Reference Electrification Model
RESCO	Renewable Energy Service Company
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
RVE	Remote Village Electrification
SERC	State Electricity Regulatory Commission
SEB	State Electricity Board
SHS	Solar-Home System
TERI	The Energy and Resource Institute
TPDDL	Tata Power DDL
WTP	Willingness-to-Pay
UIDAI	Unique Identification Authority of India
UDAY	Ujwal DISCOM Assurance Yojana

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Chapter 1

Introduction

Asato ma sadgamaya
Tamaso ma jyotirgamaya
Mrtyorma amrtam gamaya
Lead me from untruth to truth
Lead me from darkness to light
Lead me from death to immortality

-Excerpted from Brihadaranyaka Upanishad, an ancient Hindu text

Most every piece of literature on challenges around universal electricity access in low income and developing countries around the world begins with a set of statistics on the almost intractable magnitude of the problem: for example, "more than a billion people around the world still lack access to electricity" with "600 million people in sub-Saharan Africa" and over "300 million people in India alone." However, instead of continuing to build on the enormity of these figures just yet and what such a magnitude implies for the future of electrification planning, I want to hone in on "the problem" itself. In particular, I would like to invite you, as the reader, to pause and ponder the meaning of the following three words from both their technical and social perspectives:

Power (n): the rate at which energy is supplied or energy per unit time; politics, the ability to influence or control the behavior of people;

Distribution (n): the part of the electric system after the transmission system, which is dedicated to delivering electric energy to an end user; the action of sharing something among a number of recipients, the way in which something is shared and spread over an area;

Utility (n): a business that supplies a public service (as electricity) under special regulation by the government; the "usefulness" or satisfaction that a consumer obtains from any good.

Ironically, the intertwined etymology of these words illustrate "the problem" of electricity access in developing contexts all too well, with the majority of challenges persisting increasingly as a result of complex dynamics embedded within the social-political definitions of power, distribution, and utility, rather than the technical components of the system. To provide a concrete example, while simultaneous technological advancements in both grid and off-grid renewable-energy based systems and innovative digital finance platforms continue to accelerate, the poor nonetheless spend three to ten times more of the percentage of their already sparse and variable income on energy than middle and high income households do in the same country. Moreover, a large majority of energy poor consumers can end up paying an additional portion of their low income on unsafe fuels such as kerosene and diesel generators as a means of mitigating against unreliable and poor quality electricity access (ILO [2015]) – another problem of an enormous magnitude that is not encompassed in the statistics mentioned in the beginning of this introduction and whose effects are still generally poorly quantified (Lee et al [2017]). These are only a few brief illustrations, yet the astounding gaps in these social and technical definitions – and the subsequent ways in which associated metrics and concepts are defined, measured, and communicated in public discourses around universal access and energy poverty – stretch far and wide across the sector. Such disparities have rippling effects that extend from individual-level psychological impacts on the attitudes, perception, and behavior of different stakeholders to physical variability in the current fragmented and messy landscape of access around the world. Ultimately, the individuals that arguably continue to lose the most and fall directly in the nexus between the social and technical interface of the electricity distribution sector are the low-income consumers or the energy poor.

This thesis puts these individuals – the energy poor – who have traditionally been given woefully inadequate voice and attention, at the center of nearly every question and ensuing discussion. In particular, I organize the remainder of this thesis into three main essays that centralize the deep layers of meaning embedded in "power," "distribution," and "utility," and their interaction with low-income consumers' attitudes, behavior, and decision-making across electricity options into a past-, present-, and future-oriented discussion. Namely, in Chapter 2, I utilize a mixed political economy approach to answer the overarching question of how did we get here and what does 'here' entail, through an examination of the institutional, financial, regulatory, socioeconomic, sociopolitical, and technological context of the distribution sector of India, as a core case study country. Next, in Chapter 3, which is largely structured as a state-of-knowledge essay, I integrate insights from both India and other regions of the world to examine what the 'here' or aforementioned context analyses imply for present challenges related to holistically measuring and understanding welfare and consumers' willingness- and ability-to-pay for different electricity services over both short and long-term time horizons. Specifically, I motivate this chapter with a discussion on why a more nuanced approach to measuring welfare, utility, and demand is necessary in low-access settings and present in-depth literature and illustrative case studies on socioeconomic, demographic, behavioral, and technical parameters that influence these variables. Ultimately, in Chapter 4, I bridge the insights from the previous essays to identify practical, consumer-centered recommendations for integrated grid and off-grid business model planning, considering the question: where can we go in the future, knowing what we know now? I conclude with a series of questions that future researchers can prioritize in order to tackle these forms of systemic challenges in the distribution sector of many low income and developing countries.

Before jumping into it, I would like to highlight one more word: namely, *empower* or to strengthen the ability of individuals to control their life and claim their rights. Advancement toward the end of energy poverty largely hinges on enabling – or, better, *empowering* – the energy poor to become active and vocal participants and contributors to the processes involved in extending access to reliable electricity services. As such, this thesis ultimately aims to complicate how we characterize "the problem" of access and contribute to a growing movement that focuses on augmenting the voices of the energy poor, understanding the multifaceted set of factors that influence their behavior and day-to-day decisions, and incorporating a mix of anecdotal narratives and empirical insights into future models that create sustainable value and give power (physically and socially) to those who have been previously marginalized. After all, we as researchers, practitioners, and policymakers have a humbling magnitude of lessons to learn from the people behind the statistics.

Finally, I want to conclude by returning to the opening excerpt of this introduction, which derives from an ancient Hindu text. I came across this poem in reading an intensive anthropological study on the culture of lights carried out in Bihar, one of the states in India with the greatest number of citizens lacking access to power. In this paper, Kumar [2015] explores the dynamic interactions between lighting sources and their connection to deeply ingrained and timeless concepts of honor and perception in rural Indian society – including the ways in which light can spiritually signify victory over darkness, good over evil, knowledge over ignorance, and hope over despair. While the scope of "the problem" across numerous contexts can sometimes seem wickedly insurmountable when more is learned about it and can bring forth concerns about the latter points – namely, darkness, (political) evil, ignorance, and despair, – the more nuance that is applied to our extended understanding of "the problem," the more victory, good, knowledge, and hope prevail.

Thus, with this, let there be light.

Chapter 2

Challenges of Electricity Distribution in India: A Context Analysis

India's power sector is a leaking bucket; the holes deliberately crafted and the leaks carefully collected as economic rents by various stakeholders that control the system. The logical thing to do would be to fix the bucket rather than to persistently emphasize shortages of power and forever make exaggerated estimates of future demand. Most initiatives in the power sector are nothing but ways of pouring more water into the bucket so that the consistency and quality of the leaks are assured…Roughly speaking, about 60 percent of the power produced is billed and about 60 percent of that is collected…Can we honestly run [this] power system sustainably?

-Shri Deepak Parekh, former Chairman of Infrastructure DFC (Mukherjee [2014])

If you look at the distribution sector in India, in spite of help from so many directions, we have not been able to break the ice…After so many flips and flops and snail pace progress, we find again that the losses compile…something, somewhere is wrong…even if people want to help us, they might not be helping to address the actual problem. We need to think outside of the box – the conventional systems will not work.

-Dr. Amit Bhargava, UPERC (Bhargava [2017])

In a vast range of low income and developing countries, electricity distribution can present among the most daunting of collective action challenges (Olson [2009]), wherein the citizens regard electricity to be a public good, in spite of its nature as a private good (Scott and Seth [2013]). From an infrastructural perspective, overcoming this collective action issue of deploying and adequately maintaining a widespread and highly elaborate system such as the electricity grid mandates the structured involvement of a number of different organizations, public authorities, and private firms. These sets of stakeholders are often interlinked in complex ways that exacerbate these challenges at an institutional level, while opening the provision of reliable infrastructure to gaming and political capture, which further snowballs into various forms of reverberating financial, social, and political barriers to improving structural problems (Sovacool [2014], Auriol and Blanc [2009], Kumar et al.

[2012]). This pattern of widespread negative feedback loops arguably characterizes the distribution sector of India, as strongly echoed in the opening words of this chapter.

In spite of six decades of post-independence government reforms, pledges, and efforts to provide universal access to electricity, including the movement to privatize generation in the power sector in the 1990s, roughly 20 percent of the population continue to live in the dark (Kale [2014], IEA [2015]). Moreover, these statistics are often gross underestimates of the magnitude of access challenges, given both inconsistencies in how electrification metrics are defined by the government,[1] as well as the different financial and psychological costs imposed to the millions more living with unreliable electricity (Jain et al. [2015]), in spite of a paradoxical surplus of generation (Mahapatra [2017]). Notwithstanding the dynamic nature of the electricity sector in India and varying sets of opinions expressed across the range of stakeholders interviewed during three trips to India, one theme continues to emerge as a constant: namely, the need for widespread changes and comprehensive approaches to a system that has, up until recently, perceived the meaning of energy access and poverty through binary, rather than multidimensional,[2] tiers of measurement (Bhatia and Angelou [2015], Angelou et al. [2014]), and further discounted the importance of better understanding demand-side consumer behavior and perception (Khosla and Chunekar [2017], Borofsky et al. [2015]). In this pivotal time for accelerating inclusive progress on global sustainable development goals, from UNSDG7 to government commitments in the Paris Climate Agreement, the moment is ripe for rethinking approaches to electricity access in a country known for its *two faces*, where “on the one hand, the economy is booming [and] on the other, there are regions where time seems to have stood still for centuries" (DW [2015]).

While the remainder of this chapter is largely a descriptive context analysis, it is guided by an underlying aim to situate the motivation for a new and integrated approach to electrification in both the complex historical and current context of numerous dimensions of the power sector of LIDCs, such as India. The following chapters, or essays, of this thesis and core research questions that underpin them are difficult to consider in isolation of the multiplex and overlapping dynamics that have shaped the status quo of the

[1] After October 1997, according to the new government definition, a village would be declared electrified if: “(1) Basic infrastructure such as Distribution Transformer and Distribution lines are provided in the inhabited locality as well as the Dalit Basti hamlet where it exists; (2) Electricity is provided to the public places like Schools, Panchayat Office, Health Center, Dispensaries, Community Centers, etc.; (3) The number of households electrified should be at least 10% of the total number of households in the village” (DDUGJY). As of January 2018, according to Grameen Vidyutikaran (GARV) or the government-run application for monitoring village and household electrification, while 87% of 18,452 villages have been declared electrified, only 8% of those villages, or 1,264 villages, have ostensibly achieved 100% household electrification (GARV).

[2] See, for example, the World Bank ESMAP Group’s “Beyond Connections: Energy Access Redefined” report, which lays forth a new multidimensional and multi-tiered foundation for thinking about and measuring energy access, for example taking into consideration the parallel use of multiple fuels or the spectrum of applications that arise from diverse grid and off-grid technologies. The consumers generally move into higher tiers (0-5) as capacity, duration, quality, reliability, legality, affordability, and safety of the energy source improves” (Bhatia and Angelou [2015]). This more disaggregated form of measurement and data is important before “governments can now choose from a wide range of supply solutions that are not always equal in terms of the amount and quality of energy provided” (Lee et al. [2017]).

power sector and deep-seated mindsets of all stakeholders involved. Consequently, this chapter organizes existing and future work around the overarching question of *how did we get here and what does 'here' entail?* In particular, I will draw from existing literature, data, and first-hand semi-structured interviews to illustrate: (1) the institutional, financial, and regulatory contexts, (2) the socioeconomic and sociopolitical contexts, and (3) the technological context, with some introductory commentary on the important ways in which these three spaces interact with one another and how these factors can influence the types of decisions made by relevant stakeholders. Ultimately, I will conclude this section by setting up the framework for the topic area and stakeholder in the electrification system who will be the main focus of the remainder of this thesis, namely the consumer.

2.1 Institutional, Financial, and Regulatory Context

The heart of the problem is in the distribution activity – distribution has to be understood in a broad way: we don't need to do the same thing for everybody, we have to have intelligent ways to do smart cross-subsidization, reduce costs, introduce digital management and advanced technologies, and overcome the political resistance.

-Dr. Debajit Palit, TERI (Palit [2017])

Over the course of the last century, policies and programs enacted by the Indian government related to rural electrification have undergone numerous waves of change. In spite of repeated reforms and initiatives, many researchers have found little evidence of widespread success (Palit and Bandyopadhyay [2017], Kumar et al. [2012]), with some going as far as to question the overall welfare effects and long term economic development outcomes of rural electrification (Burlig and Preonas [2016], Lee et al. [2016b]) as compared to "other types of projects that may yield better returns for the poor" (Khandker et al. [2012a]). Moreover, progress in rural electrification programs have been further constrained by the institutional weakness of regulators (Kumar et al. [2012]), as well as the recurrent bankruptcies and poor financial state of distribution companies,[3] leading to government bailouts – such as the most recent UDAY scheme for clearing the debt of government utilities.[4] This not only leads to subsequent challenges of moral hazard, or a phenomenon of "too big to fail," but can also largely suppress the confidence of private investors, thereby stifling sector growth (Auriol and Blanc [2009]). In order to pave the way forward toward novel approaches to electrification in resource constrained settings, it is first imperative to understand the ways in which

[3] In 2015, according to the Government of India, outstanding debt stood at $66 billion. Drawing from Maithani and Gupta [2015], between 1998-99 and 2009-10, the gap between average cost of supply and average revenue has risen from INR 0.76 to INR 1.45.

[4] The Government of India launched UDAY in 2015 to address yet another incidence of distribution company debt. The scheme involves a transfer of 75% of the debt as of September 30, 2015 to the state governments in order to enable the discoms to make investments toward improvement of metering and operational performance. While UDAY has appeared to help make some improvements, its overall success is contingent upon sustained involvement and efforts from each of the state governments, regulators, utilities, and consumers (Palit and Bandyopadhyay [2017]).

governance and policies for both grid and off-grid systems have evolved into the current status quo (Palit and Bandyopadhyay [2017]). Given that a comprehensive overview of the entire structure of the power sector in India is beyond the scope of this thesis (for this, please refer to Kumar et al. [2012]), I qualify from the outset that the ensuing discussions in this chapter and subsequent chapters center around distribution, with generally little attention to generation and transmission. This section provides a high level temporal overview of key policies and mandates related to electricity access in India, the main government ministries and regulatory bodies involved, and financing considerations, as well as some preliminary comments on pertinent ongoing debates in this area. Specifically, I first outline the central-state structure of the sector and briefly discuss core policies and institutions. Second, I shift the focus to reforms, regulations, and policies that specifically relate to rural electrification. Lastly, I highlight a number of relevant and current debates specific to financing, including public-private partnerships, distribution franchises, and customer choice – which is an element of a larger discourse around carriage vs. content.

2.1.1 Central vs. State Jurisdiction

In spite of the tremendous growth that the Indian power sector has undergone since independence from the British in 1947, financial and political constraints have continuously rattled the sector through various stages of its history and periods of reform. In the first steps of organizing the sector after independence, the central government created State Electricity Boards (SEBs) that gradually took on complete responsibility for power activities throughout the country. Over the following decades, however, these SEBs, which depended on government transfers and suffered from entrenched political patronage and corruption, accumulated widespread losses and "eroded the states' ability to supply other social services" (Kale [2014], Tongia [2003]). Eventually, these financial crises culminated into three sets of attempted economic liberalization reforms in the early, mid, and late 1990s. In the first phase, a number of states, including Uttar Pradesh, Haryana, Andhra Pradesh, Rajasthan, and Orissa, aimed to restructure and "unbundle"[5] their respective SEBs toward greater commercialization of activities, yet short of full-fledged privatization (except in Orissa, whose privatization of distribution nonetheless did little to assuage theft and financial challenges) (Santhakumar [2008], Bhatia and Gulati [2004]). In the second phase of structural reforms in the mid-1990s, different states recognized the need for improved management of tariff design and thus created Electricity Regulatory Commissions, with the central government establishing the Central Electricity Regulatory Commission (CERC) in 1998 to better harmonize the procedures for states to establish their own regulatory commissions. In the third wave of reforms in the late 1990s and continuing

[5] Unbundling, in this context, broadly refers to the process of restructuring the power sector to separate transmission, generation, and distribution activities and move toward greater levels of competition. This generally contrasts with state-owned vertically integrated utilities, in which all activities are coordinated under one umbrella and characterizes the structure of the SEBs in India post-independence and pre late-90s and early-2000s reforms. In many cases, unbundling and privatization can go hand in hand, with the latter largely being a source of political contentiousness in India (Aklin et al. [2014], Santhakumar [2008]).

into the 2000s, the central government worked to coordinate strategies for reforming the entire sector, with a particular focus on targeting longstanding inefficiencies embedded in the distribution segment, from installing meters and overcoming theft to considering new funding mechanisms (Tongia [2003]). The key hallmark of this third reform period is arguably the Electricity Act of 2003 (E-Act), which aimed to develop national level competitive electricity markets, unbundle all of the SEBs, provide full choice to consumers and generators, establish major roles for state-level actors, and more clearly delineate state and central universal service obligations for rural electrification (Palit and Bandyopadhyay [2017]), including enabling off-grid renewable energy as an additional form of power provision for rural electrification (Graber et al. [2018]). The core central and state government and regulatory bodies that work to implement and further expand upon the E-Act of 2003 include the Ministry of Power (MoP), CERC, State Electricity Commissions (SERC), the Central Electricity Authority (CEA), and Ministry of New and Renewable Energy (MNRE), among others. Further details about the main agencies of interest to the discussions ahead are outlined in Table 2.1, while Box 2.1 provides in-depth specifics about the E-Act, as well as key sets of revisions and amendments it has undergone since it first passed in 2003.

Table 2.1: Main Power Institutions in Indian Electricity Distribution Sector

Agency Name	**Description of Responsibilities**
Ministry of Power	Established in 1992, the MoP serves as a liaison between the central and state governments, as well as the private sector. The MoP also oversees electricity production and development and maintenance of generation, transmission, and distribution infrastructure.
Ministry of New and Renewable Energy	Established in 1992, the MNRE develops and deploys new and renewable energy to supplement energy requirements, and further created state nodal agencies to promote and finance projects that enable the growth of renewable energy use in states and union territories. The MNRE also leads multiple initiatives related to access in rural areas and drafted a National Minigrid Policy in 2016, which will be discussed in greater depth in the following section of this chapter.
Central Electricity Authority	First created in 1948 and expanded upon through the Electricity Act of 2003, the CEA establishes key technical standards for different components of the electricity system and generally advises the central and state governments and regulatory commissions on all technical matters related to generation, transmission, and distribution.
Central Electricity Regulatory Commission	CERC was first created in 1998 under the MoP Electricity Regulatory Commissions Act to rationalize tariffs and develop transparent subsidy policies. As of 2003, it obtained quasi-judicial status. CERC primarily coordinates with the CEA through the task of regulating tariffs of central government discoms, inter-state generating companies, and inter-state transmission tariffs. CERC further interfaces with the MoP, state regulators, and the Appellate Tribunal to settle consumer grievances.
State Electricity Regulatory Commission	SERCs for each state were established to determine and regulate tariffs for intra-state operations, such as bulk and retail tariffs for customers and regulation of intra-state transmission.
Forum of Regulators	The Forum of Regulators (FoR) was constituted by the Indian government in the E-Act and is comprised of the Chairperson of CERC and chairpersons of SERCs. The FoR is responsible for

	harmonization and coordination of regulations, in order to promote greater regulatory certainty in the electricity sector.
Rural Electrification Corporation	The REC was set up in 1969 by the Companies Act to finance and promote rural electrification projects all over the country, providing loans to central and state utilities, SEBs, rural cooperatives, and private developers.

Source: Author Compilation, 2018 and (Levi [2016], Graber et al. [2018], Kumar et al. [2012]).

Box 2.1

Principal Features of the Electricity Act of 2003

- Harmonized previous policies, including the Indian Electricity Act of 1910, Electricity Supply Act of 1948, and ERC Act of 1998;
- Unbundled SEBs and aimed to provide a better political and regulatory environment for private sector participation in generation, transmission, and distribution through de-licensing of generation and licensing of transmission, distribution, and trading of electricity;
- Mandated establishment of SERCs and further delineated regulatory responsibilities at state and central levels; including creating an Appellate Tribunal to hear appeals against CERC and SERC decisions;
- Enacted stronger provisions against electricity theft and mandated metering of electricity supply;
- Established core clauses for fulfilling complete rural electrification, including the creation of the National Electricity Policy (NEP) and Rural Electricity Policy (REP); the permission of standalone generation and distribution for rural and remote areas; and further provisions for the management of rural distribution by panchayats (village councils), cooperative societies, NGOs, and franchisees. In particular, Section 8.6 of the REP allows tariffs for decentralized distribution systems to be set according to mutual agreements between the supplier and consumers;
- Legitimized formation of distribution franchisees to improve access to electricity in rural areas, by enabling the appointment of any person or entity to manage distribution and supply on the behalf of the distribution licensee within the licensee's area of supply, through some form of a concessional arrangement without actual transfer of ownership.

Source: Author Compilation, 2018, Palit and Bandyopadhyay [2017], Mukherjee [2014], and Graber et al. [2018]

There have been a number of important revisions that have been proposed in 2015 to amend the E-Act, with features related to encouraging retail sale competition through the separation of carriage and content in the distribution segment. These, and additional, ongoing debates related to distribution reform will be discussed later on in this section.

2.1.2 Rural Electrification Reforms and Policies

There have also been a number of important strides that have been made to attempt to advance rural electrification targets since the passage of the E-Act and subsequent National Electricity Policy and Rural Electricity Policy. Two government programs, in particular, continue to play an integral role in expanding access through a combination of grid and off-grid strategies: (1) the *Deendayal Upadhyaya Gram Jyoti Yojana* (DDUGJY) program of the MoP and Rural Electrification Program[6] and (2) the *Remote Village*

[6] This program was originally called Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) and was subsumed by DDUGJY in 2014. RGGVY had the initial ambitious goal to provide universal access by 2009 – which was obviously not accomplished and needed restructuring.

Electrification Program (RVE) of the MNRE. The former, or the DDUGJY – in combination with the original *Rajiv Gandhi Grameen Vidyutikaran Yojana* (RGGVY) together include numerous core features aimed at facilitating the goal of universal access. Specifically, the programs target electricity connections, with a preference for grid extension unless it is deemed unfeasible, for all Indian villages with 100 people. The program costs are covered by a combination of subsidies and preferential loans from the MoP and REC, with full subsidization of free connection for BPL households (Maithani and Gupta [2015]). Moreover, the updates since 2014, with the onset of DDUGJY, involve provisions for separating agricultural and commercial/household electricity feeders and metering the feeders, transformers, and customers (Ministry of Power [2014]). While these government-run and funded programs are ostensibly meant to ensure 6-8 hours of reliable electricity supply, reality has been quite divorced from these targets and enforcement of incentive mechanisms, such as converting grants into interest-bearing loans, has been weak (Maithani [2017]). The second key government program, the RVE program of the MNRE, complements DDUGJY by providing off-grid renewable-energy based electricity (largely, standalone solar systems), to remote, grid-inaccessible hamlets with fewer than 100 people (Palit and Chaurey [2011]). In spite of the growth of these programs and numerous other central government initiatives that aim to enhance the process of rural development and electrification (see Table 2.2), Bhattacharyya [2006] argues that the programs suffer from financial and implementation inefficiencies due to their multiplicity and the funding burdens it places on the state governments. Consequently, the state distribution companies have "shown less interest in promoting these schemes actively" (Palit and Chaurey [2011]), which begs the question about the ways in which private sector actors and developers could play a role in filling such investment gaps, as well as addressing challenges of poor quality and unreliable supply.

Private participation in the distribution of electricity in India is a salient and contentious topic, with various sets of associated political and financial risks that will emerge in discussions throughout the remainder of this thesis. Nonetheless, private sector involvement exists and has grown in recent years in both the grid and off-grid spaces, through different combinations of models such as public-private partnerships (PPPs), distribution franchises, and concessional arrangements,[7] including potential collaborations with rural cooperatives to be involved in metering, billing, and collection tasks (Ernst & Young [2007]). Many of these grid-based arrangements, however, have largely catered to urban and peri-urban access challenges (Sinha [2017], Shakhti Foundation [2017]) and broadly shown mixed results (Pudakalkatti [2017]). In the off-grid sector, there has also been a good deal of private involvement in universal access, leading even to the creation of a large-scale consortium of off-grid developers in 2014,

[7] Drawing from World Bank [2016], PPPs can take multiple forms and exist on a spectrum, depending on the level of involvement and risk-sharing between the public and private entities. Common types of arrangements include: utility restructuring and decentralization; concessions; build-operate-transfer (BOT) and design-build-operate (DBO); joint ventures and partial divestiture; and contract plans and performance contracts.

called the CLEAN Energy Access Network, based in Delhi. The majority of these private developers face a wide array of costly challenges, including customer acquisition and management, limited bank financing, access to and lack of certainty about subsidies, concerns over uncertain arrival of the grid, and various state discom threats. The role and challenges faced by private actors in both grid and off-grid electrification will be expanded upon in greater depth in subsequent chapters, including a brief discussion about some implications in the following socioeconomic and sociopolitical section of this chapter. Here, specifically, I will comment upon relevant working regulatory policies that aim to better bridge and address poor coordination and harmonization between both public and private agents and grid and off-grid electricity provision.

Regulatory oversight of off-grid developers has, until recently, been largely overlooked in the policy sphere in India. However, in 2016, the MNRE released a draft National Policy for Renewable Energy based Micro-Grids and Mini Grids, complemented by additional state-level micro-grid policy guidelines that continue to undergo consideration in Uttar Pradesh, Bihar, Odisha, and Madhya Pradesh (Graber et al. [2018]). The latter national draft policy is underpinned by five core principles and objectives: (1) to mainstream renewable energy-based mini-grids in the process of accelerating access to affordable energy services; (2) to increase the efficiency of project development procedures for renewable energy service companies (RESCOS); (3) to enable greater rural needs-centered innovation in the mini-grid business models; (4) to strengthen access to central finance assistance and subsidies; and (5) create frameworks for symbiotic operation of micro-grids with the relevant discom grid (Energetic India [2016]). The last two objectives bear particular relevance to the state-level policies, with a specific focus on the policy published by Uttar Pradesh, which proffers both state and non-state subsidy options and a so-called *exit option* for micro-grid developers who want to change locations. Moreover, the policy discusses the need for formalizing procedures for the grid to absorb micro-grid assets or provide for grid-compatible micro-grids (UPNEDA [2015]). While this interface between the grid and micro-grid providers has not been completely formalized, the CEA technical standards and financial agreements are generally followed by the relevant parties involved and may impact the direction of future draft policies, business models, and ongoing regulatory debates in this space (Levi [2016]).[8]

[8] Please refer to the thesis of Patricia Levi for a deeper investigation of the feasibility of grid-compatible micro-grids and relevant policies in the Indian context.

Table 2.2: Timeline of Main Rural Electrification Initiatives

Year	Scheme/Programme
1974	Minimum Needs Programme includes rural electrification into concessional support scheme.
1988	Kutir Jyoti Yojana (KJY) provides central government funding to states for single point lights for BPL HHs.
2001	RVE Programme initiated by MNRE to electrify remote HHs with renewable sources.
2004	Accelerated Rural Electrification Programme (AREP) interest subsidy scheme combined with KJY to electrify 100,000 villages and 10 million HHs.
2005	RGGVY launched with 90% grant support and 10% loans for complete village electrification by 2009.
2009	DDG Scheme of RGGVY to deploy mini-grids to electrify villages where the grid cannot be extended.
2010	National Solar Mission launched; promotes solar home and street lights and mini-grids in rural areas.
2014	DDUGJY subsumes RGGVY, and provides support for separating domestic and agricultural feeders.
2017	Saubhagya program launched to supply electricity to all HHs by December 2018, with free or low-cost connections.

Source: Adapted from (Palit and Bandyopadhyay [2017]).

2.1.3 Pertinent Ongoing Debates

In this final section, I will briefly touch upon two ongoing, and in some sense, connected debates that (1) relate closely to the development of new business models and regulatory structures for enhancing the coordination of grid and off-grid providers, and (2) advance progress toward segregating the distribution network business and electricity supply business through carriage and content separation.

Off-Grid Distribution Generation Based Franchisee (OGDGBFS) Model

The OGDGBFS model is under discussion within the Forum of Regulators in India (Patara [2017]) and potentially holds promise as a successful business model for the deployment of off-grid community based renewable energy projects. Drawing from ABPS [2011], in the OGDGBFS model, off-grid project developers will form franchisee agreements with the discom in the region and have responsibility for providing electricity to and most directly interacting with the consumers, while collecting the same tariff as that paid to the local discom. Moreover, the discom would provide feed-in tariffs[9] to project developers, while receiving central financial assistance (CFA) from the Government of India for its promotion of off-grid rural electrification. While some researchers and entities that have examined and compared the

[9] Feed-in Tariffs (FiTs) are payments that are provided to ordinary energy users for the renewable electricity they generate.

OGDGBF model to other business models argue that it provides the maximum revenue guarantee and would best enable large-scale, sustainable deployment of off-grid projects (ABPS [2011]), others are more skeptical: “[the model] still once again breaks down over the question of how to ensure that discoms will pay higher than normal rates to decentralized power plants, and does anyone actually trust that they will pay?” (Patara [2017]). Such challenges around the credibility of enforcement will be a recurring topic of discussion throughout this thesis, with deeper implications in Chapter 4, which focuses on strategies and recommendations for breaking gridlocks toward progress.

Carriage and Content Separation

In addition to such conversations about new business models for better integrating off-grid distribution generation based services with the grid, there have also been several key revisions that were proposed in 2014 and 2015 to amend the E-Act of 2003, including encouraging retail sale competition and consumer choice through segregation of carriage and content (see Box 2.2 for details). The proposal recommends a three-stage process of implementation, including functional division of distribution companies (1-2 years), preparation for competition through reduction of cross-subsidies and upgrading metering (2-3 years), and phased introduction of retail competition (FoR [2015]).

Although there has been a lull in carrying these amendments forward, the discourse over providing choice to consumers continues to be active, with varying opinions on its potential to improve competition and correct for pervasive inefficiencies in the distribution segment of the power sector. In particular, there are concerns over the prospect of low participation and how much such a restructuring could benefit small consumers – who constitute the majority of the consumer base in India – as compared to larger consumers (Dubash and Singh [2005]), which carries important potential political consequences and could further erode consumer trust in energy companies (Singh [2016a]). Moreover, there is some worry that these majority small consumers will over-rely on the provider of last resort (PoLR), thereby exacerbating the financial health of both the PoLR and discoms, which can further derail improvements in the quality of service. A number of state power departments have expressed additional concerns around accountability that consumers will face difficulties with obtaining connections since they will need to go through both the distribution company and retail supply company and would not know who to complain to if problems arise (Singh [2016a]).

Box 2.2

Proposed Electricity Act Amendments (EAA) 2014: Customer Choice

- Separate distribution (wires) function from retail supply and enable multiple supply licensees in an area, with a single (government-owned) distribution company in an area;
- Establish intermediary company in area that takes over existing power-purchase agreements (PPAs) of current distribution company and allocates them among various retail supply companies (allocation procedure yet to be decided);
- Create a provider of last resort (PoLR) who will supply electricity in cases where a consumer's retail supply company fails, and also likely to those consumers who are unable to enroll with a retail supplier.

Source: Author Compilation, 2018, (FoR [2015]).

In spite of the regulatory and political uncertainties that exist with both the OGDBFS business model and the consumer choice amendments to the E-Act, there may be a future scenario in which the two initiatives could synergize. For example, Smart Power India [2017] argues that "in case of such an eventuality [of carriage and content separation], the micro-grid operator's role could evolve into an enhanced Retail Supply Licensee in the future." Under this arrangement, regulators would need to establish strong standards of performance for the retail supply licensees and incentive structures to better ensure enforcement and implementation of good quality of service for the consumers.

2.2 Socioeconomic and Sociopolitical Context

In India, there is very little evidence to suggest that regulation has had a positive impact on quality…the regulatory authorities laying down standards do not have the teeth…to penalize the providers/sellers for non-compliance [and they are thus] unlikely to have an incentive to invest in resources for improving quality of service…consumer satisfaction in the power sector is very low (Singh and Mitra [2010])

During a meeting with regulators in Delhi in January 2017, a government actor, who requested to be only quoted anonymously, said "there are many clashes of interests – the power sector in every state is the most politicized of any sector. The local-level politicians decide things, not state utilities. The institutional framework for how things actually work is very complex and insane, with micro-politics and micro-policies." Fast forward to six months later in a semi-structured interview in July 2017 with researchers at The Energy and Resource Institute (TERI) and representatives from Tata Power DDL (TPDDL), these same sorts of sentiments were echoed from a different angle: "In India, we don't have a lack of knowledge about best practices. We don't need more research. We need to just act and actually implement the ideas we talk about – that is what is lacking. The E-Act of 2003 is one of the most beautiful pieces of legislation. Things would be different in India if we actually implemented it" (Das [2017]). What these two interviews convey in separate, yet complementary ways, is a commentary on the ways in which weak governance, electoral politics, and corruption, compromise the ideal implementation and social legitimacy of many of the programs, policies, and reforms discussed in the previous section – no matter how compelling they look on paper.

The high demand for and value that citizens place on electricity services in many low income and developing countries can make the sector susceptible to considerable politicization and capture, often evidenced by the repeated promises and (in)actions by politicians seeking votes and support of particular groups (Scott and Seth [2013]). This problem is particularly salient throughout the power sector in India, where state elections often lead to the provision of free power to farmers, a trend that was established by the Congress party in the 1977 Andhra Pradesh elections (Tongia [2003]). For example, in a study based in Punjab in northern India, Jain [2006] found that many farmers would either bribe front-line staff or use political connections to obtain electricity access. Moreover, in later studies, Badiani and Jessoe [2011] show that the level of electricity subsidies for agriculture tend to increase significantly in the year before elections, and Golden and Min [2012] find that power thefts are often supported or overlooked by governments due to concerns about losing votes. This so-called "subsidy syndrome" (Palit and Bandyopadhyay [2017]), which affords a great deal of bargaining power to agricultural consumers who pay minimum charges and most often lack metered connections, has widespread long-term consequences that permeate well beyond the cronyism that is prevalent during election cycles.

These post-election consequences are manifest along a number of dimensions, including stalemates in tariff reform; prolonged lack of financial sustainability and accruement of gargantuan losses and liabilities by distribution companies, resulting in consistently poor supply of reliable power; and numerous subsequent impacts on consumer psyches and attitudes.[10] With regards to tariff reform and rationalization, the following words spoken by the Director of Tariffs in a meeting in July 2017 at the Uttar Pradesh Electricity Regulatory Commission resonate strongly with accounts in the literature: "Anything against the government is not possible...in spite of being an autonomous body, we are not totally free nor independent. If a regulator is being paid by the state government, they cannot take a decision against the state - the set-up is completely in favor of conflicts of interest" (Bhargava [2017]).[11] This prime example of Stiglerian regulatory capture (Stigler [1971]) ensures that market distortion is pervasive throughout the entire sector and perpetuates widespread viability gaps, which are defined as the gaps between the cost of supplying electricity in rural areas and the revenue collected from consumers (Pérez-Arriaga [2017]). As discussed in depth in Kumar et al. [2012] and Dubash [2005], regulators and, in some cases, utility employees, are often appointed through

[10] More information on this latter point can be found in the following "essay" of thesis, in Chapter 3.

[11] Please refer to Kumar et al. [2012] and Dubash [2005], as well as a number of studies conducted by PRAYAS, for many case examples discussing similar issues of a lack of independent regulation. For example, Dubash [2005] references another study on five states in India that found that "state governments influence the regulatory process by simply asking state controlled utilities to not file for tariff revision at politically inconvenient moments [and] directed state-owned generating companies that sell power to the distribution companies to slash their rates even at the expense of incurring losses, so that no tariff revision at the distribution end is necessary."

political connections, rather than competence, and further depend on state grants to fund their activities. The political stronghold that is maintained over regulators and utility employees, respectively, often suppresses state regulators from enforcing logical tariff adjustments and pushes utilities to purchase power from more expensive, politically favored bidders. A confluence of these overlapping and self-reinforcing governance and market failures have repeatedly muted the benefits of many of the aforementioned interventions and rural electrification programmes, and moreover financially debilitated state electricity boards and distribution companies to the brink of bankruptcy.

The negative financial feedback loops and politicization of the power sector - particularly the distribution segment - not only creates a politically uncertain and unreliable ecosystem for investors (Ananth [2017]) (for both grid and off-grid technologies), but has moreover severely compromised the quality of power provided. As discussed in Karlan et al. [2016], "the drive toward quantity often comes at the expense of quality - given relatively low infrastructure budgets with the desire to spread over large areas often results in subpar infrastructure for the vast majority." The expansive provision of below cost-of-supply electricity and unmetered connections in the past decades, compounded by the financial insolvency of utilities and their inability to meet growing demand, ultimately partially underpin the biggest blackout in history in July 2012, which left over 700 million citizens without electricity for two days (Pidd [2012]). However, such incidences of load-shedding, poor reliability of supply, and blackouts are not isolated, but rather endemic daily occurrences. This not only creates an enormous burden and barrier to growth and productivity for businesses (Allcott et al. [2014]),[12] and households[13] but also exacerbates a growing culture of mistrust and negative reciprocity[14] between consumers and service providers, which further translates into continuous electricity theft (Gaur and Gupta [2016]).[15] The high levels of theft and uncollected tariffs, which are collectively referred to as *non-technical losses* and in many states account for 60% of losses, further compounds the substantial viability gap between the cost of supply and collected revenue for distribution companies. This additionally paves the way for other forms of inefficiencies with potential long-term

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[12] Drawing from Allcott et al. [2014] and the 2005 World Bank Enterprise Survey, "one-third of Indian business managers named poor electricity supply as their as their biggest barrier to growth. According to these managers, blackouts are by far more important than other barriers that economists frequently study, including taxes, corruption, credit, regulation, and low human capital."

[13] A recent World Bank study found that an increase in average availability of electricity at the village level increases the rate of household adoption by 2.7% and electricity consumption by 14.4%, signifying huge potential gains to consumption from modest improvements in service and that "with improved reliability, electricity may play a stronger role in improving income and productivity, as ensuring access is not enough" (Khandker et al. [2012b]).

[14] This situation can be viewed as somewhat analogous to another vein of literature related to tax morale and tax evasion, in which it has been argued that behavior around and beliefs about paying taxes is closely related to concepts of reciprocity toward the government (Luttmer and Singhal [2014]).

[15] In the 2013 documentary *Katiyabaaz,* residents in the industrial town of Kanpur in Uttar Pradesh have claimed they will not pay the discom because of the belief that the government and discom are stealing from them. Furthermore, in New Delhi in 2014, Katakey [2014] described the following scene: "BSES Rajdani Power entered a village in New Delhi on May 21, hunting for meters that were tampered with to show artificially low power consumption. Residents stoned and beat them with iron rods, a police report shows. Inspectors visiting a nearby village in 2012 were bound and urinated on, say two company officials."

behavioral consequences: “in a study done last summer [2016], we found that 90% of consumers had both grid and micro-grid connections and were customizing their own needs for hours of service from one or the other" (Palit [2017]). While such consumers may be acting rationally to address their needs, the overall welfare benefits of multiple connections as a coping mechanism to accommodate poor government electricity service provision and reliability is questionable. This topic will be examined at length in the following consumer-focused essays (or chapters) of this thesis and is broadly of growing interest among many researchers in this field.[16]

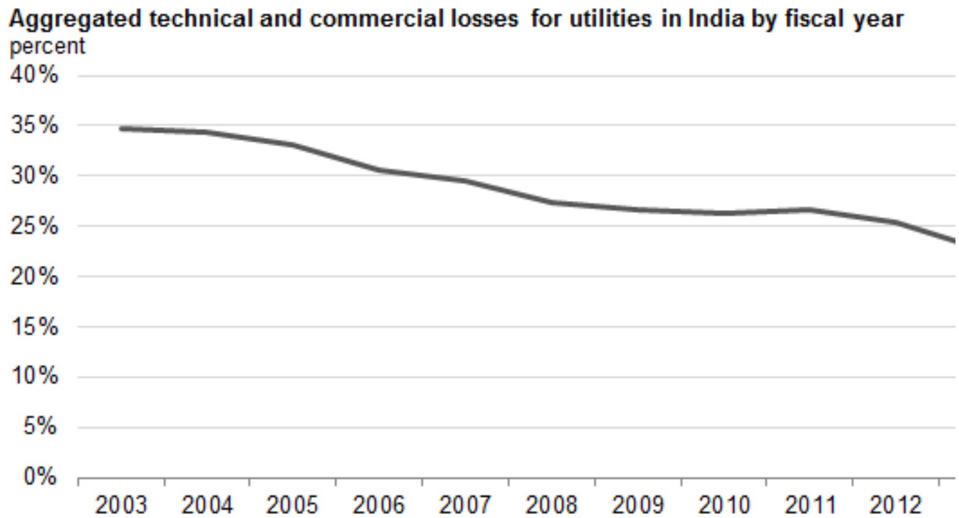


Figure 2-1: Source: EIA and CEA, 2015

2.2.1 Inequality of Access

This irrational financial architecture of the unreliable distribution segment of the power sector in India and overall annual failure to rationalize tariffs, in spite of mandates laid out in the E-Act of 2003, has significant adverse implications with regards to inequality of access. For example, in a relatively recent paper focused on analyzing slums in India, Aklin et al. [2015] find through simulations that while households in urban areas have an 80% chance of being electrified, this number falls to 70% and 50% for peri-urban and rural households, respectively. Moreover, these values are likely overestimated, as households located in states with low corruption and leftist governments tend to have, on average, better access than those with higher degrees of malfeasance and discriminatory practices. For example, Saxena and Bhattacharya [2017] find that scheduled castes (official name provided to the lowest caste in India), scheduled tribes, and minority religious groups appear to face more discrimination in terms of equality of access to electricity and liquid petroleum gas distribution. Another part of these disparities may be attributed

[16] For example, one of the four topic areas in Oxford University’s Energy and Economic Growth (EEG) program’s 2018 call for research proposals is on electricity reliability in developing countries.

to the challenges embedded within attempted cross-subsidization schemes: commercial and industrial consumers are charged a rate above the cost-of-service even though the supply is unreliable, which encourages these users, who are generally financially better off, to set up their own private reliable and personal welfare-enhancing generation mechanisms (Kumar et al. [2012]). This outcome backfires on efforts to provide better rates to the poorest tiers of society, given that the revenue of the distribution companies falls and thereby pressures them to raise the tariffs even more to compensate for the losses in a vicious downward cycle. The continued negative impacts of these factors on the financial health of the utilities, further combined with the significantly lower paying capacity of rural communities, preempts the service providers from being able to cover the capital, operation, and maintenance costs of extending the grid and providing last-mile connections to rural households. While promising efforts were made starting in 2005 to try and address these last-mile challenges through a rural franchise model for distribution and revenue collection,[17] after 2012-13, the model began to break down (Power for All [2017]) in spite of initial success in improving the financial viability of the distribution companies. This disintegration can largely be attributed to the fear held by many distribution company employees about this model serving as a gateway to privatization - a topic that is very politically controversial in India (Santhakumar [2008]; Lal [2005]),[18] but is nonetheless also dynamic and may become more attainable, in some form, in the future. Distribution franchises will be discussed in greater depth in Chapter 4.

Inequity of access further extends to the distributed off-grid space as well, which has grown to over 200 private distributed energy service companies (DESCOs) since 2012 (Power for All [2017]) in India. Although once perceived to be a sustainable solution and panacea to many of the aforementioned rural access challenges, micro and mini-grids have faced their own similar sets of problems as with the grid, as reflected in the words of a professor interviewed at IIT Bombay in January 2017: “Whenever micro-grids get fancier, the same issues that cause rural grids to fail may also affect micro-grids [like electricity theft] - they operate the way they do because they are outside of regulation and the moment they come under regulation, I am unsure what will happen...I think they are still microcosms of the bigger grid and will face the same problems" (Jadhav [2017]). The financial non-viability of many micro-grids throughout the country became obvious during meetings with numerous stakeholders operating in this space - from the CLEAN Energy Access Network of off-grid operators to specifically SELCO Foundation (Jaffer [2017]) and Tara Urja

[17] The rural franchise model was operational in over a dozen states and primarily depended on almost 5,000 Self Help Groups (SHGs) for meter reading, bill distribution, and new connection management. The preliminary results of this approach were largely positive: the distribution companies obtained higher revenue stability, there were reductions in theft and increases in customers, and the SHG model created jobs for rural women and youth (Power for All [2017]).

[18] In a recent survey study conducted in rural villages in Uttar Pradesh, Urpelainen [2016] found that 65% voiced a preference for government leadership in rural electrification, as compared with 26% in favor of private companies playing a key role. Moreover, in a meeting in New Delhi in Summer 2017, an interviewee who requested anonymity said “the only model for private participation in India is a franchisee. Full-fledged privatization is not going to come any time soon to India…public ownership of the networks and assets is something that is emotionally attached.”

(Patara [2017]) - in July 2016, January 2017, and July 2017. As discussed in Palit and Chaurey [2011], many of these mini-grid projects struggle financially and ultimately dissolve as a result of numerous factors, including high electricity generation, capital, operation, and maintenance costs due to the remoteness of communities, as well as low paying capacity for many consumers and general perceptions that off-grid electricity is socially inferior or fake (Borofsky [2015], Kumar [2015]).[19] Moreover, the risk of central grid extension and arrival - which is the policy repeatedly promised and touted by the government - and lack of widespread assurance of regulation for grid-compatible micro-grids further discourages private investment to help the sector grow and reduce costs (Levi [2016]). In order to maintain some level of operable viability, these mini-grids, which often function out of the sight of regulators, end up charging exorbitantly high tariffs from consumers. Additionally, as discussed in Singh [2016b], it is relatively common for customers and field practitioners to observe sales agents selling low quality products and then disappearing when the product needs service or maintenance[20] - a phenomenon which further stifles the market, given the unwillingness of rural communities to purchase solar technology from new firms after having heard about the bad experiences of others through word-of-mouth and peer network effects (Rogers [2003]). Such means of implementing business functions not only fosters distrust between consumers and service providers, but also engenders greater disparities between the rates paid and services experienced by main grid and mini-grid consumers (Palit and Bandyopadhyay [2017]).

Another troubling dimension of this problem is the ways in which micro-grid site selection procedures can perpetuate inequalities *between* rural communities. For example, as discussed in an interview in January 2017 in Bangalore with a representative from the SELCO Foundation, "Wherever there is more success is where there are livelihoods that depend on the mini-grid, for example commercial enterprises and shops are dependent on it for their livelihoods and there is a cluster of these types of entities in a close-knit space – it is under these conditions that pilots have worked somewhat better" (Jaffer [2017]). While it arguably

[19] In an interview with a representative from SELCO, Borofsky [2015] discusses the following: "I would argue that at the local level, the perception that solar is inferior is as much fueled by the economics, i.e. in the discrepancy in the cost to consumers between off-grid electricity and subsidized grid electricity, as it is by the politics and political messaging around electricity access throughout India. While none of the factors are strictly labeled as *political*...the perception that solar and other forms of off-grid electricity are second class is probably an outgrowth of national and state-level political campaign promises of free or very cheap grid electricity…I mean we have heard of villages backing out of [SHSs] because some politician…told them if you put solar in your village then it is likely to be de-prioritized on the grid expansion road map…people feel like they are spoiling their chances of getting grid into their village because the government will see they have light already…I think its mostly myth, but perception makes up various things."

[20] In a Skype interview on June 21, 2017 with an Indian government official, who has spent the past year on sabbatical traveling around the country conducting research for his PhD in Political Science and has requested to be quoted anonymously, the following troubling stories were reported from the ground: "After 5 months [since the inauguration of a microgrid promising 24-7 access], only 64 households out of the 197 dwellings have received power – and by power I mean just 1 7W LED bulb. I managed to get my hands on the survey estimating customer demand for this project, which was conducted 5 years ago and it promised 2 fans and 2 lights to every household. Since the micro-grid was inaugurated, people have continually kept asking when they would get more than their single light-bulb. One woman saved money and bought a fan and the moment she plugged it in, her power supply went out. People here do not understand load limiters – they just remember what they were promised and when the power fails to deliver that, they distrust the service provider…and there is not even a village energy committee for a project that is supposedly a community-run micro-grid."

makes business sense to seek out locations where aspirations and opportunities for productive uses of electricity are higher, as it better ensures potential for demand growth and revenue collection, this strategy nonetheless continues to discriminate against access for the most impoverished households and implies the need to conceptualize more integrated and universally inclusive solutions. Although there are solutions that would show a great deal of promise, such as a reactivation of the consumer-centric and flexible distribution franchise system where DESCOs can use their own generation and sell power at a weighted price (Power for All [2017]) and discoms would actually be willing to work with micro-grids and engage franchises, this requires changes in regulation (Palit and Bandyopadhyay [2017]) and actual enforcement of the universal service obligation law (Patara [2017]). The relationship of utilities and off-grid providers with their elusive customers, and the ways in which the lack of a sustainable relationship perpetuates inequality of access, among other problems, is another active area of research than will be further developed in the following essays of this thesis.

2.3 Technological Context

The disturbing evidence is that losses (and theft) appear to be increasing in an era of readily available technological means (metering, for instance) to lower non-technical losses (Smith [2004]).

While much of the existing literature, - as reflected in the words of Smith above, - and first-hand interviews across the country indicate that many of the obstacles present and embedded within the processes of rural electrification are social and political in nature, there are nonetheless a number of technological developments and applications that are important to consider in this dynamic space. Given the sets of problems that have continued to transcend different waves of reform in electrification initiatives in India – as well as many countries in sub-Saharan Africa –, government actors, industry stakeholders, and researchers in relevant fields have, in recent years, turned to various technological interventions to try to address some of the social, political, financial, and regulatory issues highlighted in previous sections. Thus, the core research questions that guide the following section include: (1) *What are the main technologies that are currently being utilized or considered for use to strengthen government and/or private actors' role in improving electricity access in LIDCs?* And (2) *What known effects, if any, have these technological interventions had on addressing relevant social, political, financial, and/or regulatory challenges?* These technological interventions can broadly be characterized into three core categories: (1) E-Governance and Civic Participation Platforms, (2) Digital Finance Service Applications, and (3) ICT-based Smart Technologies and Computer-Aided Supply Optimization Platforms. In order to provide a complete picture of the electrification landscape, the following section aims to supplement the largely historical, yet nonetheless continually relevant, context analysis of the earlier sections with a very current analysis of the present state of technology solutions and ideas for addressing universal access in developing countries. I will first discuss some of the main advancements made along these three categories, and further highlight open-ended questions and concerns that remain, given that the effects of such technological interventions continue to be highly active areas of research. Ultimately, I will conclude with a brief introduction to a new technology platform called *blockchain*, which has grown immensely in importance over the last couple of years and may hold some potential to address a number of challenges pertaining to corruption, bureaucratic red tape, electricity theft, and lack of transparency in electricity distribution. Details regarding blockchain can be found in the Annex of this thesis.

2.3.1 E-Governance and Civic Participation Platforms

Drawing from Kalsi et al. [2009], electronic "e-" governance or "enhanced" governance can be defined as the processes and structures that are necessary for the government to deliver electronic services to the public, collaborate with business partners, and orchestrate electronic transactions, while ensuring maximum transparency, right to information, stakeholder participation, and reduction of delays in government operations. Interest in and applications for e-governance in developing countries has grown in recent years, with a number of studies highlighting promising opportunities for e-governance and e-procurement to enable trustworthy service delivery in places with limited state capacity. For example, drawing from a recent impact evaluative study conducted by Banerjee et al. [2016] on an electric fund flow (from the central to state to local implementing body) reform to the Mahatma Gandhi National Rural Employment Guarantee act (MGNREGA)[21] in Bihar, the authors found that the policy reduced monetary leakage, allowed for more effective auditing, and reduced lags between fund transfer and receipt. Furthermore, in a case study analysis of e-procurement of public works (road) infrastructure in India, Lewis-Faupel et al. [2016] find increased bidding ability of firms outside the contract region and better infrastructure quality. While these studies do not explicitly relate to electricity policy and planning, their applications can extend well to the field. For example, e-governance and e-procurement platforms can be applied to address issues relating to the independence of regulators, such as the problem of utilities purchasing power from more expensive, yet politically favored bidders. Moreover, they can be applied to improving the security of viability gap funding and subsidy dispersal. Although these preliminary studies in this growing body of literature evaluating ICT-based governance voice qualified support for the capacity of such reforms to advance the delivery of public services and improve financial transparency, including in the power sector, there are nevertheless reasons to maintain some degree of skepticism if these technical interventions are not

[21] MGNREGA is an Indian labor law and one of the world's largest social welfare programs. It aims to guarantee a *right to work* and enhance livelihood security in rural areas through the provision of at least 100 days of wage employment in a financial year to every household whose adult members volunteer to do unskilled manual work. If work is not provided within 15 days of applying, applicants are entitled to an unemployment allowance.

complemented by long-term trust and institutional capacity-building. As discussed in Dhaliwal and Hanna [2014]:

> "it...follows that technological improvements in monitoring to increase the probability of getting caught engaging in wrong behavior...should, in theory, better align the bureaucrat's incentives to the government's. However, just monitoring [one problem] may not necessarily improve [and maybe exacerbate] the program outcomes if the bureaucrat needs to undertake a series of different tasks - and not just the monitored one - to improve outcomes."

In addition to digital reforms for government fund transfers and procurement, the current administration in India has also been actively pushing forward an ambitious and controversial agenda to bring India's population into the digital age through a number of civic engagement applications ostensibly meant to enhance participation (see Table 2.3 for details about government apps specifically related to electricity access) and a digital infrastructure of APIs called the India Stack. In particular, the India Stack aims to take the country toward a presence-less, paperless, and cashless service delivery system, and largely relies on a groundbreaking biometric 12-digit unique identity system called Aadhaar, which is run by the Unique Identification Authority of India (UIDAI). Considered the world's largest national identification project, the Aadhaar system is important to conversations regarding the technological dimensions of rural electrification largely for the ways in which it is purportedly constructed to enhance equitable financial inclusion, bringing millions of formerly un-banked citizens into the formal banking sector, and for the mechanisms it utilizes to reduce corruption, black market operations, duplicate accounts, and leakage in the transfer of public funds and services (Banerjee [2016]). For example, using its features of uniqueness, authentication, financial addresses, and e-KYC (know-your-customer), the Government of India directly deposits subsidies, including Liquefied Petroleum Gas (LPG) subsidies under the Direct Benefit Transfer of LPG or PAHAL scheme[22] and funding for the MNREGA employment and welfare scheme, into the bank accounts of the Aadhaar number holders (UDAI [2017]) and further interfaces with mobile banking sector through the central government's JAM Initiative (Jan Dhan - Aadhaar - Mobile) for financial inclusion. While it is still a bit too early to fully believe in the proclaimed "phenomenal success" of this program (Lahoti [2016]), it nonetheless may have significant implications with regards to the potential implementation of conditional or unconditional government cash transfers for electricity (Palit [2017], Bhargava [2017]). For example, in a discussion about subsidies in July 2017 with the Director of Tariffs at UPERC, Bhargava [2017] said: "subsides have to be digital – people will receive the corresponding subsidy from the central or state government in their personal accounts, linked with their Aadhaar – like in the India Stack. The government should create something like a mix of conditional or unconditional cash transfers directly into peoples' accounts – where you give, for example, 3 Rs and

[22] The PAHAL scheme was launched in June 2013 and enables LPG customers to get subsidies directly into their respective bank accounts in over 291 districts. The Aadhaar card can be linked to consumers' bank accounts to get the direct benefit of the subsidy.

out of those 3, 1 Rs is unconditional and the 2 Rs is conditional and locked away for the purpose of energy-related expenditures…I believe Haryana Electricity Regulatory Commission has already started a subsidy disbursement directly to customers – like an unconditional cash transfer model."[23] In a similar form of dialogue at TERI in July 2017 Palit [2017] discussed the following: "the government is thinking about direct cash transfers for electricity…this is already being done for LPG, but for kerosene it is more political – what the government is thinking of doing is to put in a 40 Rs cash transfer into peoples' bank accounts and then they can go to the market to buy fuel and use Aadhaar to prove eligibility – it is still under discussion about whether to make it conditional or unconditional. I think it should be unconditional, but I don't know what the government is thinking." It is thus evident that such applications in e-governance and civic engagement are under active discussion in both government and research circles and may hold high level of potential for overcoming a number of the stubborn negative feedback loops addressed earlier in this essay. The following sub-section will briefly further expand on closed related technological advancements in digital financial inclusion and the ways they intersect with mobile banking and payment services for low-income electricity consumers.

2.3.2 Digital Financial Service Applications

Impact evaluative research throughout different countries has shown numerous benefits of the rise of digital financial services, from reducing transaction costs and improving risk-sharing in informal banking (Jack and Suri [2014]) and increasing the financial independence of women (Suri and Jack [2016]) to strengthening government means for transferring cash (Karlan et al. [2016]). In the rural electricity sector, in particular, digital finance and mobile banking have skyrocketed in usage - largely in sub-Saharan Africa - for the ways in which it facilitates both micro-payment/ micro-credit, and appliance leasing schemes, with a specific focus on off-grid technologies (both micro-grids and solar home systems). While one of the most well-known examples of the mobile pay-as-you-go system is that of M-KOPA,[24] in partnership with the mobile banking company M-Pesa in Kenya, Tanzania, and Uganda, there are nonetheless a few companies that have begun to adopt this model in India as well. In fact, the momentum for PAYG solar in the Indian market has been growing rapidly in 2018, with huge potential benefits, including increasing consumer ability-to-pay, providing companies with direct links to their consumer base, and giving some level of insurance to the consumer against malfunctioning products (Power for All [2017]). A few of the companies that have tapped into this nascent market in India include Simpa Networks, BOOND, and OMC Power. In the model adopted by these companies, customers pre-pay based on actual energy use through their mobile

[23] Though Singh [2017] argues in a paper through the Center for Global Development that, in India, "end-user financing (i.e. consumer subsidies and tax rebates) is relatively ineffective at enhancing sales of off-grid solar technologies [because it] relies on formal banking systems and hinders firms from passing on subsidized costs because of extenuated bureaucratic cost recovery." While e-governance schemes may help to alleviate these bureaucratic challenges, it is still too soon to know their impact.
[24] KOPA means "borrow" in Swahili.

phone and each time a payment is made, the SHS is unlocked for a certain amount of energy consumption in kilowatt-hours and when the payment is exhausted, the system is temporarily disabled until the next payment; ultimately, when all payments are made, the product is permanently unlocked (ADB [2013]). While most of these systems have thus far been confined to basic lighting services and mobile charging, in June 2017, Simpa launched a product called the Magic TV, which is the country's first solar-powered PAYG satellite television (Alliance for Rural Electrification [2017]).[25]

Such technologies can further extend to other appliances that households aspire for, yet cannot currently afford, as well as to the grid, through the implementation of mobile-oriented pre-paid metering and perhaps, even, pay-as-you-go for facilitating payment of costly connection fees. The intersection of digital financial services and rural electrification efforts can not only help to address challenges of income and credit constraint faced by the poorest households by improving ease of payment and building credit histories, but has also been shown to partially reduce delinquent payment behavior and theft (Jack and Smith [2016]). Moreover, such forms of digital-based services can enable future additional features in mobile applications that can improve communication and feedback systems between service providers and consumers (see Chapters 3 and 4 for more information). At the same time, however, there are several difficult hurdles to overcome in order to take PAYG solutions to scale in the complex market in India, including policy fluctuations, capital constraints, and competition from kerosene subsidy schemes (Power for All [2017]). Moreover, it should be noted it may continue to be a number of years until mobile money systems truly take off at a mass economy of scale in India, given the level of familiarity and dependence on cash in rural economies.[26] Time will tell whether the Aadhaar digital identity system and other e-based initiatives underway will accelerate the adoption of digital and mobile financial services in the rural energy sector.

Table 2.3: Government Civic Engagement Applications

App	Year	Scheme/Programme
Garv I	2015	Mobile app launched by REC to provide data about rural electrification progress for 18,452 un-electrified villages, with GPS coordinate-linked photos of the infrastructure to allow for tracking progress in the rollout and quality of the infrastructure.
UJALA	2015	Mobile dashboard launched by PM Modi to provide real-time updates on LED distribution.
Surya Mitra	2016	RVE Programme initiated by MNRE to electrify remote HHs with renewable sources.

[25] The Simpa Networks Magic TV system is powered by an 80W solar panel, and includes 100+ free-to-air satellite television channels, with a 20-in energy efficient LED television, a powerful battery, advanced solar charge controller, and three LED lights for multi-room planning (Alliance for Rural Electrification [2017]).

[26] In a conversation in July 2017 in Bihar, a representative from Husk Power, a solar and biomass micro-grid company, claimed that "it is at least another 5 years down the line before mobile money could really take off at scale in India in this [energy access] sector – people have already gone back to demonization…it was 23% mobile money after demonization and now it is back to about 7%." Similarly, during an interview in Delhi at headquarters of Tara Urja, another micro-grid company, Patara [2017] said, "we predict it will be about 3 years before mobile money payments really take off. People are too used to cash here."

Garv II	2016	Garv I app upgraded to monitor village and household electrification; includes a citizen engagement window called SAMVAD, meaning *conversation* in Hindi, to enhance channels of feedback and suggestions, where messages are sent directly onto dashboards of Managing Directors and Superintending Engineers of discoms through SMS.
Vidyut Prayah	2016	Interactive GPS-based app launched by MoP to track real-time information on pricing and availability of electricity; meant to empower consumers to demand 24x7 power from states.
URJA	2016	Launched by MoP to help enhance urban consumer connection by showing the performance of discoms in cities and giving data on the Integrated Power Development Scheme (IPDS).
Ujra Mitra	2017	App released by MoP to track blackouts and power supply in real-time; includes complaint portal and alerts on expected duration and causes of blackouts, as well as historic outage information.

Source: Author Compilation, 2018.

2.3.3 IoT-Based Smart Technologies and Supply Optimization Platforms

As with the technological applications of e-governance and digital financial services, there are many opportunities that potentially exist with regards to the intersection of smart technologies and technoeconomic planning with rural electrification, but there are also innumerous uncertainties and lingering questions. In this final overview of the rural electricity and technology context in India and other LIDCs, I will briefly present opportunities and ambiguities that exist for technoeconomic planning tools, two-way communication platforms, and smart system technologies to strengthen the role and impact of government and private actors working toward universal access.

Technoeconomic Optimization and Planning Tools

Planning efficient networked systems and maintaining a dynamic perspective with regards to ongoing technological changes is a research-intensive and intricate challenge. There are a number of projects, however, that work to develop computed-aided, geospatial supply optimization software targeting these issues with a specific sensitivity to planning for both grid and off grid-based rural electricity access in LIDCs. A few of these current projects include the Network Planner Tool from Columbia University (Kemausuor et al. [2014]), the OpeN Source Spatial Electrification Toolkit (ONSSET) from KTH in Sweden, the International Finance Corporation's Off-Grid Market Opportunity Tool (Dodd and Markoglou [2016]), and the Reference Electrification Model (REM) from MIT and Comillas Pontifical University (Borofsky [2015], Ellman [2015], Cotterman [2017]). This latter model, in particular, has grown through several generations of students in our research group within the MIT Tata Center for Technology and Design and is currently used for applications in India, Colombia, Kenya, Rwanda, Uganda, and Nigeria. The optimization software utilizes information about areas with poor electricity access to determine the best electrification mode (namely grid-connected, micro-grids, or isolated systems) for each household or other load center, estimates cost and electricity demand, and simulates preliminary network designs for grid and off-grid systems, among other functionalities. While the model and its capabilities around simulating demand and reliability profiles will be further expanded upon in Chapter 3, or the following essay of this thesis, further details of its more technical capacities can be found in the theses of Douglas Ellman, Matthew Brusnahan,[27] Olamide Oladeji,[28] Cailinn Drouin,[29] and Stephen Lee.[30]

Reliance on such forms of technoeconomic optimization and planning tools for expanding electricity access can come with both advantages and disadvantages. On the one hand, GIS-based energy access decision tools can be utilized by private actors and government agencies involved in planning and implementing national electrification schemes to make streamlined and efficient assessments of electrification options from a least cost perspective (Gibson [2017]), while including different forms of trade-off analyses with regards to the reliability levels of the electrification options. On the other hand, these decision analysis tools often tend to take a top-down approach that can fail to adequately integrate ground-level energy poor perspectives, consumer demand profiles and behavior, different forms of risk, institutional barriers, and sociopolitical and financial complications that can arise from market distortions, such as those from energy consumption subsidies. Furthermore, as argued by Gibson [2017], most of the existing technoeconomic optimization and decision support tools currently do not offer platforms for addressing pay-as-you-go (PAYG) SHS business decision needs, with ONSSET currently holding the most potential on this front. Moreover, such traditional methods for infrastructure planning and design optimization of systems, which tend to have a bias toward the objectives of least-cost and maximum technical performance outcomes, can oftentimes overlook issues such as inclusivity and distributional and equity effects. In spite of these challenging limitations, these GIS-based energy access decisions tools, such as the Reference Electrification Model, hold a great deal of potential for modification and expansion in future years, as more is learned and understood about consumer behavior, distributional impacts, and effective ways in which to integrate bottom-up perspectives into socio-technical models. This thesis, which in some aspects builds upon the previous work of Borofsky [2015], aims to support the process of closing these gaps between top-down and bottom-up planning for electricity access and expanding approaches for inclusive development in both grid and off-grid energy systems in LIDCs.

Two-Way Communication Platforms and Smart System Technologies

[27] Matt's thesis focuses on a version of the Reference Electrification Model called LREM or "Little REM" and explores micro-grid designs for improving service, financial viability, and risk mitigation for off-grid electricity systems in India and sub-Saharan Africa.

[28] Olamide's thesis focuses on the recommendations of the least cost mode of electrification and the clustering of consumers to minimize overall distribution investment cost, applying computational methods that focus on partitioning the expected distribution network if all consumers are connected to the grid, as compared with other approaches.

[29] Cailinn's thesis focuses on the application of REM in Rwanda and specifically examines the ways in which the model integrates consideration of topography and other geographical constraints.

[30] Stephen's thesis and research focus includes applications of deep learning-based approaches to building footprint extraction from satellite imagery, applying Bayesian models for estimating electrification status of buildings and investigating decision-theoretic approaches to infrastructure and information planning in LIDCs.

In addition to the aforementioned advancements in the development of technoeconomic optimization tools, there has been increasing progress in the application of two-way communication technology in the energy and electricity sector. Such IoT-based smart technologies and intelligent infrastructure, such as smart metering systems, have the potential to transform methods of issue diagnosis and customer service by monitoring the performance of grid-connected or off-grid system performance in real time and enabling remote management of problems. For example, a company called SparkMeter, which integrates its smart metering systems with hybrid micro-grids in Asia, sub-Saharan Africa, and Latin America, utilizes central gateways with two-way communication platforms. Their systems not only allow customers to shift load limits and pre-pay for electricity, but the meters also wirelessly connect with the central gateways and send updates to cloud-based servers every 5-15 minutes, thereby enabling remote monitoring of performance and reduction of cost response time (Buevich et al. [2014]). Such technologies further enhance companies' abilities to better learn about consumer behavior and preferences, and make personalized adaptions in order to improve efficiency, drive down costs, and address climate and energy goals. The Nest Learning Thermostat from Google, for example, has helped to save billions of kWh of energy through the ways in which it learns about consumer behavior and routines, and subsequently programs itself to monitor energy consumption (Lee et al. [unpublished]).

Beyond such examples of smart home products developed by private entities, there have also been massive strides in the public sector. In India, the current government, under Prime Minister Modi, has inaugurated a nascent and highly ambitious program called the Smart Cities Mission, which ostensibly includes components such as (1) 24/7 reliable electricity supply with at least 10 percent of the energy requirement coming from solar and smart metering, (2) 80 percent of buildings holding energy efficiency certifications, (3) demand side management (DSM) and consumer-oriented smart grid technologies, and (4) intelligent power networks with radio frequency meters that automate error-free bills (Sethi [2016]). Similar forms of initiatives are underway in sub-Saharan Africa as well, including in Kenya, Nigeria, Rwanda, and South Africa. As these public and private initiatives expand, in simultaneity with the growth of wireless telecommunication networks and Internet infrastructure in resource-constrained settings, the consumer insights and additional information provided from these smart system technologies can help to further enhance the effectiveness of complementary top-down and bottom-up electricity and access planning solutions. Overall, there is enormous potential for the deployment and implementation of smart system technologies in LIDCs to strengthen join impact in social, environmental and economic goals around energy access. At the same time, however, such technical solutions alone are not a panacea to the challenges of access and must be accompanied by strategic and harmonized national data system policies, protocols, and capacities, in order to best leverage the the data from these systems into decision-making.

2.3.4 Blockchain and Energy Access

Lastly, a final technological development that is worth noting briefly within this discourse on energy access and technology is blockchain. Touted by some as the "second generation of the Internet" (Tapscott and Tapscott [2016]), this technology is a crowd-managed and distributed database that enables direct, peer-to-peer transactions without the need for third party mediators and enables immutable execution of automated contracts between parties. In recent years, it has gained a great deal of traction as a platform for overcoming bureaucratic inefficiencies, corruption, and other forms of potential monetary leakages that may exist in different public and private systems, including within the energy sector. Additional commentary on the ways in which blockchain is currently interacting with electricity access initiatives in the LIDCs can be found in the Annex of this thesis.

2.4 The Need to Understand the Consumer

Pro-poor energy innovation can be understood as a process that explicitly involves the poor as end-users of the resulting resolutions…extensive stakeholder engagement with energy solution development and deployment is central to the long-term success of efforts to expand access (Singh [2016b]).

Much current national energy planning and international donor support is disjointed and focuses disproportionately on large infrastructure that…is not aligned with the global 2030 timeline, does not make economic sense in most energy-poor contexts, and is out of touch with the needs of the energy-poor (Practical Action [2016]).

Progress toward the goal of universal access to electricity by 2030 will require radical new ways of approaching the challenge of creating new business models, institutional coordination mechanisms, and planning policies. Considering the dynamic shifts in the distribution sector in numerous LIDCs, from the development and deployment of a wide array of digital technologies for both grid and off-grid systems to concurrent changes in regulation and policies, an integrated and comprehensive approach to equal and universal access to electricity will require a confluence of both top-down and bottom-up considerations (Pérez-Arriaga [2017]). Throughout this essay, I have aimed to paint a comprehensive picture of the present and historical context of the complex electricity distribution system in India, from (1) an Institutional, Financial, and Regulatory angle; (2) a Socioeconomic and Sociopolitical angle, and (3) a Technological angle. What I hope the reader has extracted from this foundational set-up for a remainder of this thesis is a couple of main insights to keep in the back of your mind as you continue through the subsequent chapters or essays:

1. Generally speaking, strong regulations and policies – such as the E-Act of 2003 and its ensuing amendments – exist for improving access to electricity in India, with a notable exception in the metrics utilized for measuring access and the status of "electrified" villages. However, not enough attention has been paid to entrenched and vast informational asymmetries that exist between the institutions that provide these public services and the population of citizens that receive the service,

including the politics of implementation and how well these regulations enmesh with ground-level socioeconomic and political realities. This inattention has resulted in multifarious long-term social, financial, and psychological consequences that have preempted widespread and sustainable progress over multiple periods of attempted reform in the sector.

2. While huge strides have been made by actors in both the public and private sector in India and other LIDCs to advance technological solutions to many of the challenges around electricity distribution laid out in earlier sections of this chapter, a number of these developments are still nascent and their true effects are currently difficult to measure in the absence of evidence. While each solution holds immense potential to target specific issues, I would argue that none of these technological innovations constitute a panacea, particularly those that, in their current stage, fail to adequately integrate information about the preferences and behavior of the energy poor.

Central to these insights and considerations is the need for developing better and more holistic understanding of the stakeholder that has, up until recently, been often overlooked and under-examined in the dialogue around rural electrification: the consumer. As broadly alluded to throughout this essay, the vast majority of the stubbornly persistent problems and puzzles that are ubiquitous in the distribution arm of electrification can be largely attributed to *human factors*, and consumers fall very much at the messy junction where technology and politics interface with one another. The remainder of this thesis will focus on this junction[31] and the role of the consumer in the complex ecosystem of the power sector in India. In the groundbreaking paper, "The Economic Lives of the Poor," Banerjee and Duflo [2007] discuss the $1-a-day poverty line that has dominated conversations around poverty, asking "but how actually does one live on less than $1 per day… [what are] the choices they [the extremely poor] face, the constraints they grapple with, and the challenges they meet?" Drawing inspiration from this line of thinking and questioning, as well as motivation from the growing intersection between the fields of behavioral economics and development economics (Demeritt and Hoff [2017]; Kremer and Rao [2017]; Rao [2014]), I extend these questions to the context of energy access. Namely, I aim to provide a small dent into an actively growing and young research literature that questions: how do the energy poor grapple with both a complete lack of access to electricity as well as lack of access to reliable power, and how do these situations affect both their short-term and long-term choices in grid-based and off-grid settings? Not only will a more in-depth comprehension of consumer behavior and decision-making help to inform influential strategies for building trust and acceptance from the bottom-up, it will also further advance the maturity of top-down decision-support and optimization tools by increasing their consideration of dynamic and relevant social factors.

[31] Poetically, in electrical engineering speak, a *junction* is a transition region between regions of differing electrical properties in a semiconductor. In this context, building a stronger understanding of the consumer and an integration of human-centered design frameworks into universal access planning is the "transition region" that is necessary for bringing the properties of technology and politics into a state of harmony and flow.

The following essay delves deeper into the nexus between electricity access, the consumer psyche, welfare, ability- and willingness-to-pay, ultimately setting up the framework for recommendations in Chapter 4.

Chapter 3

Determinants of

Consumer Willingness- and Ability-to-Pay: A Holistic Examination

A brief recap of the previous chapter purveys that public sector provision of electricity access is a highly complex, politicized, and dynamic topic in India (among other LIDCs), where every third citizen lacks access to energy for basic household needs - with even higher rates in rural areas of states like Bihar, Uttar Pradesh, and Rajasthan. For decades, India has faced enduring challenges of various inefficiencies in the power sector and low levels of grid reliability, struggling to deliver quality electricity at the times of day when people most need it. One popular hypothesis for these longstanding failures to reform the power sector is widespread opposition to increases in electricity tariffs, pricing, and subsidy reform (Aklin et al. [2014], Santhakumar [2008] Lal [2005]). The existing arrangement of the distribution sector relies on end-user tariff structures on a cost-plus basis, charged by state distribution companies and governed by state regulators. In particular, industrial and commercial users are charged under an incremental block tariff structure while the majority of agricultural and residential users are often charged negligible tariffs or given free, unmetered power. Although there are some differences between states, the general health of the overall system can be characterized by sub-optimal equilibria, with prolonged lack of financial sustainability and accruement of losses and liabilities by distribution companies, resulting in consistently poor supply of reliable power and repeated bailouts by the government (Garg et al. [2016]). To add to this challenge, while numerous surveys and papers document consumers' strong desire for more reliable electricity and acknowledgement that existing poor quality considerably impacts their productivity and welfare across multiple outcome measurements, a large majority also are not willing to pay cost-reflective tariffs for more reliable electricity (Garg et al. [2016], Aklin et al. [2014]).

Consequently, this essay aims to delve into a deep examination of potential determinants of this enduring opposition to increases in tariffs toward more cost-reflective pricing, in spite of preferences for better quality power provision. In particular, I begin by first considering the various and oft subjective definitions of the key concepts that are central to the ensuing discussions and framework of this essay, namely *utility, willingness-to-pay (WTP), ability-to-pay (ATP), welfare,* and associated measurements.

Thereafter, the remainder of this essay is structured into two core sub-sections that delve into a deeper understanding of factors that influence these parameters: I first focus on *WTP* for reliable electricity, and secondly, on the important dimension of *ATP* and the role of productive uses of electricity to stimulate sustained demand in longer time horizons. It is worth noting here that while measurements of WTP are often disaggregated into three categories of consumers – namely domestic, commercial, and industrial consumers – I will largely be focusing the work in this essay around domestic (household) consumers of electricity. In the first section (i.e. WTP), the structure of the essay is as follows: first, I consider the question of *why* a more nuanced understanding of WTP is necessary in countries with large-scale access deficits. Second, I briefly outline some of the main existing methods for measuring WTP and its attributes. Next, I delve into the question of *what* can be said intelligently about WTP in such contexts, deriving from a mixture of research methods. Specifically, I will consider WTP from the standpoint of socioeconomic and behavioral determinants, followed by a number of analysis of technical determinants, such as reliability and quality of power, and the ways in which these parameters affect WTP across the range of grid and off-grid electricity supply solutions. In the following section of this essay (i.e. ATP), I will highlight a number of key insights about the short-term and long-term interactions between ATP or "affordability," productive uses of electricity, and WTP, including several practical case studies from the field. Ultimately, I will conclude this chapter by underscoring a set of overall insights from this combined analysis and begin to probe the question of *how* can this information about WTP, ATP, and productive uses of electricity be used in integrative electricity access planning by governments and firms, in order to maximize impact.[32] Moreover, I will draw attention to a number of ongoing field experiments that aim to provide empirical insights around these same forms of research questions. While the questions examined throughout the different sub-sections of this essay are narrower in specificity, they are informed and shaped by the overarching spirit of inquiry in the three main questions that I have outlined here.

3.1 Terminology

In order to use the metrics of utility, welfare (as measured by the cost of non-served energy or CNSE), ATP, and WTP, it is necessary to clarify their meanings in the context of the remainder of this essay and the overall thesis. Each term can be interpreted through a variety of lenses, and are related to each other in complex and cyclical ways. In this section, I present an overall understanding of these terms, from their subjective philosophical definitions to the practical ways in which they are defined and used in existing planning models. While the puzzle of how to either separate or better integrate these measurements with each other is ongoing and unsolved, I aim to try and at least enable a basic understanding of the parameters

[32] This will be considered in greater depth in Chapter 4 of this thesis, which focuses largely on mitigation measures and planning strategies.

within the context of energy and electricity access, before adding even more layers of complexity to their meaning.

3.1.1 Utility

Utility is an ever-elusive concept and measurement that, at a high level, implies the amount of satisfaction or 'usefulness' that a particular consumer obtains from or finds in a good, service, or activity. Similarly, marginal utility represents the additional utility that is obtained from an additional unit of consumption. While it is not inherent in the good or service itself and is highly difficult to measure, utility is nonetheless important to capture, as it has a direct influence on the demand, and thus price, of a good or service – such as electricity access and electricity reliability. In the current economics literature, consumer utility and utility maximization is determined through a variety of both direct and indirect mechanisms involving consumer behavior theories, including the application of tools such as discrete choice experiments, random utility models, stated preference surveys, revealed preference experiments, and contingent valuation, the latter of which will be discussed later on in this essay.

3.1.2 Willingness-to-Pay and Ability-to-Pay

WTP is very closely related to utility and consumer satisfaction, and essentially is an indirect means of measuring and representing the elusive metric of utility. While an examination of the complex theoretical models for measuring WTP are well beyond the scope of this thesis, the general framework for calculating indirect utility and consumer satisfaction through WTP involves two core components: disposable income or ATP and various sets of attributes, such as social, utilitarian, and hedonic attributes that impact consumer choices (McFadden [1997]). With regards to the first component, the relationship between ATP and WTP is relatively explicit: WTP has an upper limit of a certain level of ATP or level of disposable income; namely, no matter how much a consumer would like to consume a particular good or service, he or she needs a baseline ability to pay for it and can only consume up to that limit. The second component of the function – namely social, utilitarian, and hedonic attributes – is where this metric becomes ever more interesting and complex, and relates closely with the discussions ahead in this thesis. In particular, utilitarian attributes are relevant to the instrumental and functional purposes of the good or service, while hedonic attributes are relevant to subjective measures such as pleasure, happiness, and social stature that good or service provides (Dhar and Wertenbroch [2000]). When consumers make decisions between various forms of goods and services, the ways in which they balance the trade-offs between attributes is influenced by an array of internal and external social, economic, demographic, behavioral, technical components that interact with each other and change the individual weights that consumers place on the attributes of a good or service.

To bring this discussion into the context of energy, the utilitarian attributes – or namely, the functional and instrumental attributes – of WTP can be broadly categorized into utility from electricity *access* and utility from electricity *reliability* (which will be sub-categorized later in the essay). In some cases, consumers may completely lack access and in others, consumers may have access but cope with various forms of poor reliability or quality of service. Each of these scenarios has differential impacts on consumers' valuation of the utilitarian attributes of their WTP for both grid and off-grid electricity services. Moreover, there are enormous differences in the social and hedonic attributes of consumers' WTP for electricity access and electricity reliability. For example, while the actual utilitarian or functional attribute of reliable electricity from a microgrid or solar home system may be much higher than that of unreliable grid-access, the perceived hedonic attributes of grid electricity may hold greater weight due to factors such as social status associated with the grid versus off-grid services. While many of these factors and scenarios will be discussed in greater depth throughout this thesis, it is important to foreshadow the complex meanings as I will be repeatedly using the terms WTP and ATP in different ways throughout the chapter.

3.1.3 Welfare and Cost of Non-Served Energy (CNSE)

"I cannot help but wonder how many medical catastrophes have occurred in public hospitals because of 'no light,' how much agricultural produce has gone to waste, how many students forced to study in stuffy, hot air have failed exams, how many small businesses have foundered."
-Chimamanda Ngozi Adichie, Nigerian author

A final elusive and dynamic measurement that is closely related to the previous ones is welfare, which differs depending on whether we are considering individual welfare or social welfare. In traditional welfare economics theory, the problem of social welfare maximization involved "weighing against each other the losses of utility and gains of utility of different individuals, [which implies an oversimplified, rational] interpersonal comparability of utility" (Lange [1942]), which is now increasingly outdated given the growing complexity in measurements of "utility." Without going into much detail on philosophical considerations of efficiency, fairness, and theories of justice that interact with the ways in which social welfare is understood, it is nonetheless clear that welfare is intimately tied to "utility" and thus WTP, and its measurement in the context of electrification can vary between social objective functions pertaining to maximization of access versus maximization of reliability, subject to different forms of financial, social, political, and technological constraints. In the current literature and optimization models for electricity planning, a metric that is used to try and capture measurements of welfare is the cost of non-served energy or CNSE, which can be further categorized in two ways:

1. In situations in which electricity access through a particular mode already exists, **CNSE-1** represents the loss of welfare to existing customers when the supply is unreliable or fails to deliver, and this can further vary based on the electrification mode (grid or off-grid).
2. In situations in which access does not already exist and the government is deciding what to allocate limited budgeting to between sectors – i.e. water, education, health, energy, etc. – **CNSE-2** represents the loss of welfare to potential customers who continue to lack access to various forms

of electricity services across delivery modes (Pérez-Arriaga [2018]).

CNSE-2 can depend on CNSE-1 and further needs to incorporate different utility values of electricity for different consumers, users, time periods, and delivery modes. I will revisit this measurement later on in this essay, when I go into a more in-depth analysis of the relationship between reliability and WTP. The following section takes these interrelated concepts and integrates them into discussions around *why* a more nuanced understanding of WTP in countries with large-scale access deficits is necessary.

3.2 Why is a More Nuanced Understanding of WTP Necessary in LIDCs?

In a very recent state-of-knowledge paper that reviewed the status, context, and political economy of power sector reforms in LIDCs, including India, Eberhard et al [2017] provide important commentary on the ways in which the implementation of the so-called 'standard model'[33] of power sector reform that was dominant in the 1980s and 1990s has largely failed in non-OECD countries, with some degree of variation between sub-Saharan Africa, South Asia, and Latin America. In particular, the authors discuss how these reforms have struggled to create positive impact in the context of "capacity shortages, weak institutions, low levels of socioeconomic development, and complex political-economy conditions" and low "political will" (Victor and Heller [2007]). Generally speaking, while there is affirmative evidence on many positive impacts of the standard model of reform in locations in which it has been successfully implemented, there is also a growing literature on the varying ways in which the likelihood of a positive outcome is extremely contingent on factors such as the starting position of the country and its power sector, as well as the political economy system of their power sectors (Eberhard et al [2017]).

While the insights from this work provide relatively broad and vague conclusions about political will and the ways in which weak political and economic institutions underlie why certain nations' systems fail, they serve to hint at the underlying motivation for *why* a nuanced understanding of WTP is necessary in countries with large-scale access deficits. In order to establish the basis for this motivation, I will approach the question from two angles: first, I will discuss how the aforementioned failures of the standard model power sector reforms have consequently paved the way for a fragmentation of the infrastructure of distribution, thereby creating a complex gradient of consumer-types and categories of access that are unheard of in high and middle income countries. Second, I will briefly introduce how consumer behavior, and the overall field of behavioral economics, is different in the setting of low income and developing

[33] In the paper, the authors broadly describe the standard model of market-based alternatives to the power sector as including steps of corporatization and commercialization of national utilities, the introduction of competition through restructuring, privatization, and allowing for the entry of private power producers, and creating independent regulatory institutions. During the period, many of these factors of the standard model or "Washington Consensus" were established as stringent conditions for power sector loans, macroeconomic stabilization lending, and development aid as part of the structural adjustment policies carried out by Bretton Wood institutions, such as the World Bank and International Monetary Fund (IMF). Such programs of structural adjustment have been critiqued as undermining national sovereignty and advancing neo-colonial or modern financial imperialism, and moreover creating large-scale debt in countries that could not repay loans.

countries, and the ways in which these differences can manifest into the complexity of how WTP – for both *access* and *reliability* of different forms – is understood (and misunderstood) in such contexts. Ultimately, given that many factors and determinants are interconnected and connected through feedback loops, it is not suitable to apply existing reductionist methods to analyzing WTP, and therefore a more nuanced approach would provide more useful insight to planners.

3.2.1 Toward a Subtler Segmentation of Energy Access

Traditionally, consumers of electricity (i.e. excluding those who are completely unelectrified) have often been subdivided into an arguably oversimplified binary categorization of the form of electricity access, namely grid-based electricity and off-grid systems of electricity. While off-grid systems are well understood to constitute micro-grids, mini-grids, and standalone solar systems such as solar home systems and solar lanterns, the gradient of the consumer base that exists between the grid and off the grid is more nuanced than how it has generally been described in the literature. Recent work from the Energy Institute (EI) at the Haas School of Business at the University of California, Berkeley has begun to challenge this paradigm, with research on rural electrification in Kenya resulting in the coinage of the term "under grid," which describes households that are close enough to connect to a low-voltage line but are not connected for a variety of reasons such as high connection costs (Lee et al [2014]). Moreover, in an insightful and reflective report published in late 2017, the SHS giant in Africa, M-KOPA, drew from its own experience working in Kenya and Tanzania to further disaggregate this gradient to include what they termed "idle grid" consumers and "bad grid" consumers (M-KOPA Labs [2017]).[34] In large part, the existence of these more intricate disaggregated categories of access result from the countless political economy challenges, – such as those discussed in the previous essay and in Eberhard et al [2017], – that have pre-empted 'standard reforms' from achieving their aims in many non-OECD countries, no matter how well intentioned. These subtler segmentations of consumers of electricity are important because each suffers from different degrees of challenges which can hold implications for consumers' WTP for the level of service within that category. For example, in some preliminary analysis, M-KOPA found interesting differences in the income levels and income sources (i.e. irregular, third-party, agricultural, business, regular) of consumers across the access gradient. Moreover, there is significant heterogeneity between rural, urban, and peri-urban consumers and how they fall and move between categories of the access spectrum. In some cases, some consumers may even fall under multiple categories simultaneously – subscribing to certain off-grid connections or turning to kerosene to accommodate or cope with their under grid, idle grid, or bad grid connections.

[34] According to the report, "idle grid" consumers include households who are connected to the grid through rural electrification programs, but generally cannot afford appliances. In contrast, "bad grid" consumers include households who are connected to the grid but suffer from unreliable connections, such as frequent and extended outages (M-KOPA Labs [2017]). See Table 3.1 for more details on these categorizations.

Table 3.1: Segmented Energy Access Continuum

Off Grid	Under Grid	Idle Grid	Bad Grid	On Grid
These consumers often live too far from the grid and can frequently utilize any and all combinations of the following possible non-grid systems for lighting and other basic appliance usage (if any): Mini/Micro-Grid Solar Home System Solar Lantern Kerosene	Under grid consumers are households who are theoretically close enough to low voltage transformers, but are not connected to the grid, perhaps because of high connection fees. In Kenya, for example, 11 percent of the population can be classified as such.	Idle grid households do have connections to the grid, yet rarely are able to afford paying their electricity bills, let alone for additional appliances, even if they aspire to own more. In Kenya, over 3.5 million households that connected to the grid with the Last Mile Connectivity Program could be classified as idle consumers.	Bad grid households can oftentimes fall into more urban or peri-urban settings with higher income levels, yet these consumers similarly do not purchase many appliances because of concerns about frequent lack of reliability or stable power supply. In Kenya, for examples, around one third of grid-connected households have a 'bad grid' connection.	This last segment of consumers enjoys largely stable and reliable electricity access from the grid and are able to own more appliances.

Source: Adapted from M-KOPA Labs [2017] and Oyuke et al [2016]

Figure 3.1A:

Percent of HH Urbanized by Connection Type

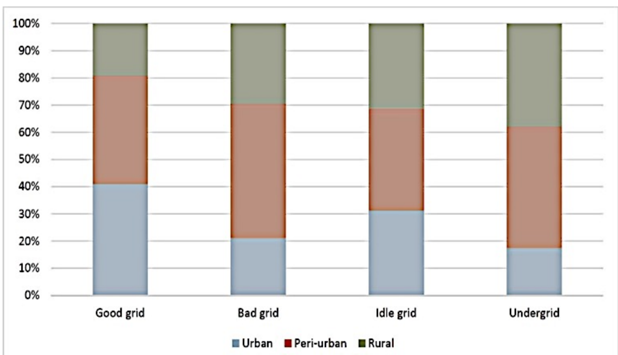
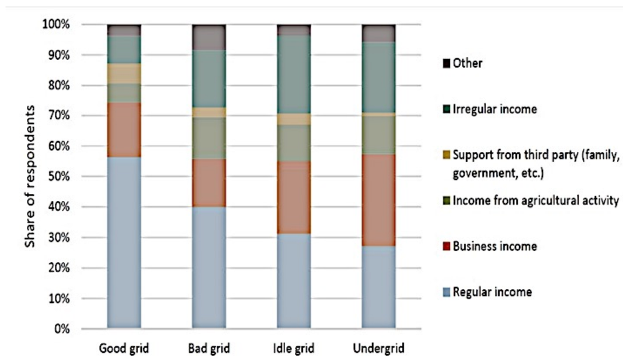


Figure 3.1B

Income Sources by Connection Type



Source: Both Figure 3.1A and 3.1B are directly referenced in M-KOPA Labs [2017].

Even though these examples above are specifically related to the context of Kenya and insights from one large company with experience operating in this setting, the implications extend far beyond the context of eastern Africa. While one should be cognizant about making claims of external validity, namely the extent to which conclusions from one context can be generalized to other situations and people, it is generally well established that widespread parallelisms do exist on some fronts between the distribution failures of systems in sub-Saharan Africa and South Asia Eberhard et al [2017]. Patterns, such as those analyzed in the M-KOPA study, and other gaps in understanding about the spectrum of energy access serve as a key motivation behind the World Bank Energy Sector Management Assistance Program (ESMAP)'s creation of a multi-tier framework (MTF) to collect data, monitor, and evaluate energy access following a multi-dimensional approach (ESMAP [2015]).[35] The high level of mobility in research on this

[35] The MTF of ESMAP redefines energy access from the traditional binary approach to a multi-dimensional definition as "the ability to avail energy that is adequate, available when needed, reliable, of good quality, convenient, affordable, legal, healthy and safe for all required energy services." This implies that having an electricity connection does not necessarily constitute having access under this definition, especially when considering issues such as reliability and affordability. In this framework, access is measured as a tiered spectrum, from Tier 0 (no access) to Tier 5 (highest access level) (ESMAP [2015]). For example, the 'under

multidisciplinary topic of realistic measurements of energy access, both in industry and academic circles, signals a paradigmatic shift that this essay and overall thesis aims to contribute to.

Now, what does this all mean for WTP for both access to and reliability of electricity in LIDCs? The fragmentation of consumers into these various buckets of categories, each with their own sub-complexities and challenges, implies, rather evidently, that there is no one-size-fits-all approach to measuring and comprehending consumers WTP for electricity services. A holistic examination of WTP, ATP, productive uses of electricity and the interplay and trade-offs involved in consumer-decision-making across this segmented continuum of access is necessary, not only to help companies to better target and customize their product offerings, but to also shift the means by which policymakers are measuring their own progress, efficacy, and accountability in reaching true universal access targets. In future sections of this essay, I will utilize a survey dataset from India to conduct extensive descriptive analysis on the variability and nuance of consumer WTP and decision-making.

3.2.2 Differences in Behavioral Economic Insights in LIDCs

A second argument that underpins the need for understanding WTP differently in contexts with energy access deficits can be illustrated by turning to a relatively new and rapidly emerging literature on the intersections of behavioral economics and development economics. Similar to previous ignorance on how differently the standard model of power sector reform would play out in high and middle-income countries versus in low income and developing countries, Henrich et al [2010] argues that psychology and behavioral economics research has placed a disproportionate level of focus on WEIRD (Western, Educated, Industrialized, Rich, and Democratic) populations. This imbalance is highly problematic, as it overlooks some glaring differences that can significantly alter what WTP means and how it is measured in LIDCs: for example, Kremer and Rao [2017] shed light on a number of the ways in which consumers in LIDCs face worse access to information and exorbitantly unstable decision environments, which further implies patterns of the poor having to self-regulate in the absence of quality assurance and consumer protection (Duflo et al [2012]).[36] Moreover, there is gradually mounting evidence on the psychology of poverty, including the "effects of scarcity, stress, sleep deprivation, pain, poor nutrition, depression, and anxiety on cognitive function and economic behavior" (Kremer and Rao [2017]). Given that populations in LIDCs that live in extreme energy poverty most often simultaneously struggle with other forms of access challenges as well – such as access to water, education, health services, stable income, and transportation – and live in unpromising decision environments, it is plausible to believe that some of these psychological variables

grid,' 'idle grid' and 'bad grid' categorizations of M-KOPA would likely fall somewhere in the middle between 0 – 5 in the MTF spectrum.

[36] In a sense, there is already some anecdotal evidence on this type of self-regulation in the field when one takes note of the existence of multiple connections by households as a means of coping with reliability challenges.

can factor into these consumers' WTP for electricity access and reliability, and the related choices that they make. Culture and social norms further add another layer of complexity to this.

Such forms of subtleties in human behavior and the cognitive biases that may be embedded in decisions that consumers make bear importance for the ways in which WTP, as well as its interactions with ATP and productive uses of electricity, is understood in developing contexts. This intersection of behavioral and development economics matters for energy access planning and analysis for the potential that it holds to "provide different diagnoses of problems and imply different policy responses" (Kremer and Rao [2017]). A more refined understanding of consumers, their behavior, and mixture of preferences is not only significant for remedying the seemingly systemic negative feedback loops that have plagued the power sector as a whole, but for ensuring a policy structure that can help to close the gaps between urban and rural, and even gaps within rural electricity access provision. Given the rise in technological developments for increasing the interface of governments and businesses with their beneficiaries, as discussed in the previous essay of this thesis, this topic moreover provides an opportunity for studying the ways in which citizen-government relations, better information provision, and social insurance may hinder or cultivate local development when eased of potential inherent animosities, information asymmetries, or difficult choice environments that may exist (Fetzer [2014]).

3.3 Contingent Valuation Methodologies for Measuring WTP

At this point, it is my hope that the reader is convinced or to at least some extent agrees that it is necessary to understand and approach WTP differently in countries with access deficits, such as India. Now, how is WTP actually measured in the current economic literature? In recent years, studies have popularized contingent valuation methodologies (CVM), which is a survey-based stated preference economic technique for estimating the value that an individual places on a good, oftentimes a non-market good. While I will not go into great detail on the technicalities of this method for public service valuation, this section will provide a brief description of different choice experiments that researchers use to measure WTP for services, such as electricity, as well as the limitations of these methods, such that the results and WTP values that will be discussed later in this essay can be understood reasonably within this methodological context. Moreover, later in this essay, I will propose a number of hypothetical experiments that, to some extent, combines certain capabilities of the Reference Electrification Model (mentioned in the previous essay) with CVM tactics in order to engender stronger estimates of trade-offs between WTP for various combinations of access and reliability. Consequently, basic background on this method is of merit. In particular, in Table 3.2, I present five different contingent valuation survey methods.

Table 3.2: Contingent Valuation Methods for Measuring Consumer WTP for Public Services

Method	Description
Single Bounded Dichotomous Choice	This is among the most common methods used by researchers and involves asking respondents if he/she will pay a specified monetary amount to obtain a good and there are only two choices: yes, or no. This monetary amount, often called a bid value, is varied across respondents and the discrete choice format mimics a bargaining process.
Multi Bounded Polychotomous Choice	In this method, respondents are presented with a *panel* of values and response categories that have been arranged into a matrix, and then are asked to mark the degree of confidence that they feel about paying or not paying for each amount that is listed in the matrix.
Payment Cards	In this method, the respondent is presented with a list of possible values on a card and then asked to pick the value that best represents his/her WTP, as well as a second choice. Oftentimes, the mean of the lower bound (first choice) and upper bound (second choice) is taken.
Choice Experiments	Next, in this method, the respondent is asked to choose between pairs of programs (programs A and B), each of which contain different attributes and costs, or to choose to 'do nothing' (i.e. the status quo), which allows the researcher to obtain information about the marginal valuation of each attribute.
Contingent Behavior	Lastly, this method asks a respondent what he/she would do under specified hypothetical circumstances. For example, in Jayne et al [1996], researchers asked respondents in Kenya, Zimbabwe, and Mozambique what their expected purchase of refined cornmeal, coarse cornmeal, or other substitutes would be under a variety of price and regulation scenarios; this stated preference data was combined with revealed preference data (from the actual purchase of these commodities) to estimate demand functions.

Source: FAO [2000]; Welsh and Poe [1998]; Louviere [1996]; Jayne et al [1996]

Each of these methods carry different advantages and disadvantages that can affect how seriously the calculated WTP values for either access t or reliability of electricity can be interpreted. On the one hand, a number of the different forms of CVM experiments presented above encourage respondents to realistically consider trade-offs in the values they choose and decisions that they make. On the other hand, these methods, as well as other stated preference methodologies, are criticized for not taking into account various forms of biases and strategic behavior that may exist among consumers. For example, Whittington [1998] discusses that in some LIDCs, survey respondents have struggled to understand what the notion of maximum WTP actually means, with one respondent equating maximum WTP with the event that "a gun was pointed to his head." In other cases, there are reports from the field of consumers altering their reported WTP, relative to their true WTP, in order to influence the provision and cost of a good or even giving so-called "protest zero" responses to signal disagreement with the scenarios provided in the survey and their belief that the government should pay for the service[37] (Hadker et al [1997]). Moreover, in the scenario of WTP for access, if a respondent is not familiar with a technology – for example a consumer who has never had electricity before – it can be difficult for them to project their own valuation of a good or service they may not understand. In some of these cases, where the consumers have not previously had exposure to the

[37] Such forms of mentalities are potentially plausible in agricultural and rural areas of India, where consumers are used to politicians' promises of free electricity (as discussed in the previous essay) and in peri-urban and slum areas where there are also widespread occurrences of electricity theft. This will be discussed in greater depth in future sections of this essay.

technology under WTP assessment, it is sometimes common for least-cost optimization and planning tools, such as those introduced in the previous essay of this thesis, to utilize data on the average tariff for kerosene as a proxy for WTP. However, Palit [2017] argues that this is also a problematic measurement, as it is the per unit cost equivalent for a lack of electricity and is thus very unlikely to accurately reflect consumer WTP for actual access. For example, in a survey conducted in six states throughout India, researchers found that consumers, for the most part, were well aware of the negative health effects of kerosene and 66.04 percent of respondents preferred that the government subsidize grid electricity, as compared to only 12.37 percent who wanted more kerosene subsidies (Aklin [2017]). Lastly, there is well established evidence that most consumers experience a cognitive bias called loss aversion (this will be explored in a bit more depth in the following section of this essay), which results in them weighing losses more heavily than commensurate gains. This phenomenon manifests itself into some contingent valuation and stated preference survey methods that find higher willingness-to-accept values, as compared to WTP values (Frederiks et al [2015]).

As such, given all of these potential limitations, even though choice experiments and contingent valuation do seem to continue to dominate the (albeit few) existing studies on WTP for access and reliable electricity across different electrification modes in developing contexts, more researchers are beginning to combine this method with revealed preference methods – i.e. WTP as measured by consumers actual spending and purchasing behavior (Rubino [2017]). The next section of this essay goes into great detail on socioeconomic, behavioral, and technical factors that influence utilitarian, social, and hedonic attributes of WTP and presents the current state of knowledge on these topics, drawing from an array of papers that utilize a mixture of these aforementioned methods of WTP estimation.

3.4 Socioeconomics and Demographic Determinants of WTP for Electricity

Socioeconomic and demographic determinants of WTP for electricity in LIDCs are among the factors that are generally better understood and well researched in the literature. In particular, variables such as educational status, income, caste, occupation, number of school children in the household, age, household structure, and whether the household runs a business all indicate interesting upward and downward effects on consumer WTP. Overall, there is a general consensus in the current literature that higher educational status or years of education is associated with greater WTP for electricity (Gunatilake [2012]), as well as an increase in openness toward subsidy and other price reforms toward more cost-reflective tariffs (Garg et al. [2016]; Aklin et al. [2014]). Similarly, in a study conducted in the state of Madhya Pradesh in India, Gunatilake [2012] found that each additional child of school-going age in a household increases WTP by 4.3 percent, which is not insignificant and, generally, if households rank and value electricity as their top government development priority (compared with water, education, etc.), they often have a greater WTP value. Higher income levels and the existence of a home business also logically imply a higher WTP for reliable electricity services. For example, in a survey experiment carried out in Kenya, Abdullah and Jeanty [2009] find that, even if consumers do not currently run a home business, if they express an entrepreneurial aspiration, they are more likely to have a higher WTP for reliable electricity. Concurrently, in India, Gunatilake [2012] also presents findings that households with home businesses have a significantly higher propensity to value electricity more, as it can help to improve the business and their productivity. On the other hand, if consumers are daily wage workers, with either an irregular income source, income from agricultural activities, or income from third-parties (such as loans from family members or micro-lenders), time constraints in their payment schedule affects their ATP, even if their true WTP is a high value. As already discussed, these income categories are generally associated with under grid, idle grid, or bad grid consumers (M-KOPA Labs [2017]).

Other parameters that have been examined in the literature have reported ambiguous effects and are thus subject to more discussion and scrutiny. In India, in particularly, one of these vague determinants of WTP is caste status, as there are plausible explanations for the direction of the effect on both sides. On the one hand, households may lack access due to social norms and/or discriminatory practices and thus may be WTP more to overcome these constraints. On the other hand, depending on their status, some households may be WTP less because of poverty or ingrained mental expectations of subsidies or free provision of power (Gunatilake [2012]). Age is another variable that has indeterminate, and potentially context or country-specific, effects on WTP. While Taale and Kyeremeh [2016] find, in a study in Ghana, that age has no measurable effect on WTP, Oseni et al. [2017] finds in a contrasting study in Nigeria that age is negative correlated to the probability of a household to engage in self generation. Interesting, in studying areas of North Cyprus that lack reliable electricity access, Ozbafli and Jenkins [2016] also find that older people tend to have lower levels of utility loss from high frequency of outages. This result may be a consequence of status quo bias, a behavioral phenomenon that will be expanded upon in the following section of this essay. Lastly, the structure of a household also sheds interesting and contradictory light on WTP outcomes. In the same study in North Cyprus, Ozbafli and Jenkins [2016] find that people who live in detached houses suffer higher utility loss compared to individuals who live in apartments, likely due to fewer opportunities to share appliances with neighbors in the case of outages. In contrast, Taale and Kyeremeh [2016] discuss that households that use separate meters have a higher WTP for improvements in electricity supply than those sharing meters. Some of these findings may potentially be underscored by interesting behavioral differences that are discussed in the next section. A summary of these findings can be found under Table 3.3, followed by a panel of basic descriptive analyses using ACCESS, a dataset on energy poverty in rural India, covering 8,565 households from 714 villages in Bihar, Jharkhand, Madhya Pradesh, Uttar Pradesh, Odisha, and West Bengal (Aklin [2017]).

Table 3.3: Socioeconomic and Demographic Parameters Affecting Willingness-to-Pay for Electricity

Parameter	Country	Description	Direction of Effect	Source
Education	India	Effects of years of education or highest educational status on WTP and openness to price reform	Positive	Gunatilake [2012]; Garg et al. [2016]; Aklin et al. [2014]
Caste	India	Effects of caste status on household WTP (Schedule Castes, Schedule Tribes, or Other Backward Class)	Ambiguous	Gunatilake [2012]
Occupation	India, Kenya	Effects of occupation (business, agriculture, informal) on household WTP	Ambiguous	Gunatilake [2012]; M-KOPA Labs [2017]
Substitutions	India	Effect of how highly households rank electricity as a government development priority on household WTP	Positive	Gunatilake [2012]
School Children	India	Effect of how many school-going children are in a household on WTP for electricity services	Positive	Gunatilake [2012]
Age	Nigeria North Cyprus Ghana	Effects of age on household WTP and loss of utility from electricity outages	Ambiguous	Oseni et al. [2017]; Ozbafli and Jenkins [2016]; Taale and Kyeremeh [2016]
Household Structure	North Cyprus Ghana	Effects of living in detached houses or with separate meters on WTP for improvements in electricity services	Ambiguous	Ozbafli and Jenkins [2016]; Taale and Kyeremeh [2016]
Home Business	Kenya India	Effects of household entrepreneurial aspiration or business ownership on WTP for reliable electricity	Positive	Abdullah and Jeanty [2009]; Gunatilake [2012]

Source: Author Compilation, 2018.

Figure 3.2A: WTP for Grid Connection by Age Across Six States

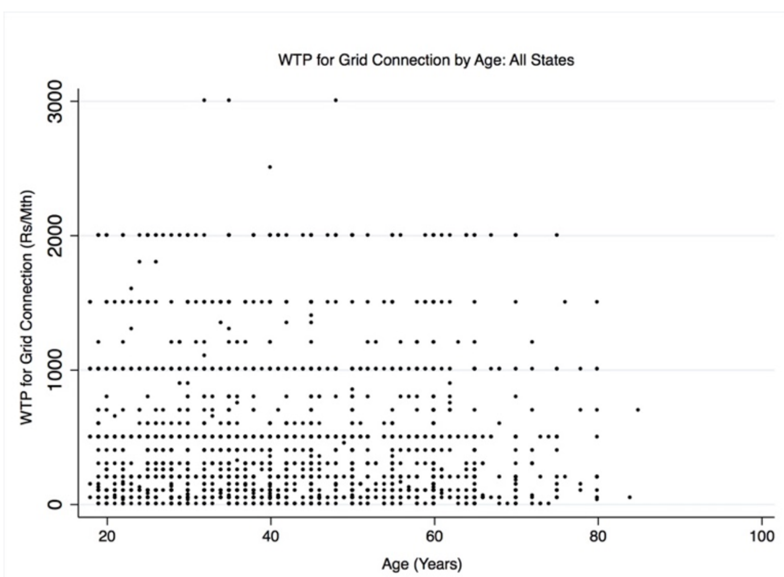


Figure 3.2B: WTP for Grid by Educational Status

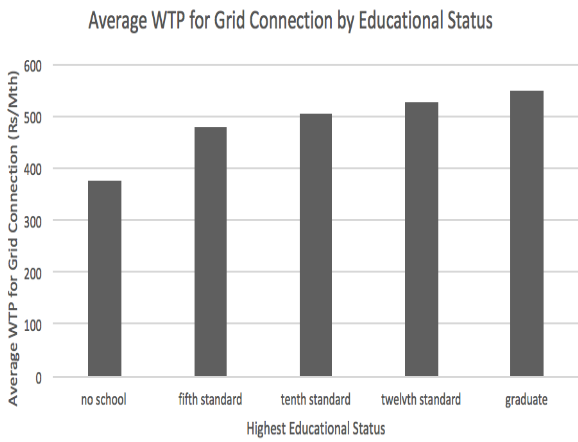
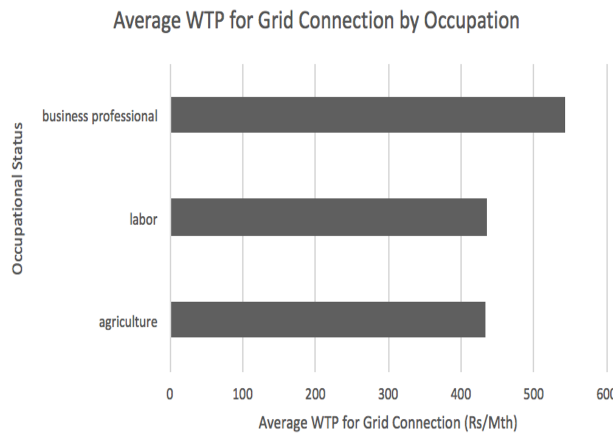


Figure 3.2C: WTP for Grid by Occupation



A very cursory descriptive observation of this recent data from six states in India (Aklin [2017]) hints at insights that are essentially well aligned with previous findings in the literature. As can be observed in the charts above, while there is not a clear observable relationship between age and WTP for electricity in the scatterplot (Figure 3.2A), there is a very apparent increasing, albeit gradually increasing, trend with regards to educational status and WTP (Figure 3.2B). Interestingly, there is a relatively minimal difference in the average WTP for grid connections between agricultural workers and labor workers, possibly due to similar income instability patterns from the occupations. As expected, however, business professionals report a considerably higher WTP. Additional trends will be examined using this same survey data later on in this essay.

3.5 Behavioral Determinants of WTP for Electricity

While the abovementioned socioeconomic and demographic factors that influence household WTP for electricity access and electricity reliability across electrification modes in LIDCs are better understood, there continues to be a general dearth of research and evidence on behavioral components of consumer preferences and decision-making. Nonetheless, there are a number of explanations that could potentially account for the low WTP for reliable power and ensuing commons dilemma. Although there are likely private incentives to free-ride in the classic collective action problem scenario (Olson [2009]), there may will be cognitive aspects to consider as well. For example, Kopelman et al. [2002] find nine classes of independent variables that influence cooperation in commons dilemmas, including social motives, gender, payoff structure, uncertainty, power and status, group size, communication, causes and frames. Drawing inspiration from this line of thinking, this section will explore and provide an overview of several behavioral factors that could play a role in this phenomenon. In particular, I draw from the current, largely anecdotal or statistically descriptive state-of-knowledge to present a set of hypotheses about behavioral factors that influence WTP across its different definitions, which future researchers could potentially test empirically in the field, in order to parse out important causal effects. Several of these hypotheses are motivated by a number of core and relatively intersectional research questions in this specific area: first, in what ways does consumer perception of the government, service provider, or other consumers affect WTP for reliable access, or, willingness to engage in various forms of theft/non-payment? Second, are consumers WTP more if they have higher levels of trust and/or satisfaction toward the government? And, lastly, how do reliability and perceptions of service quality affect consumer behavior and WTP? The latter question, in particular, provides a direct segway into the section examining technical determinants of WTP. I qualify here from the outset that while I just use the term WTP, it can encompass different meanings and relate to different utilitarian, social, and hedonic attributes depending on the context in which I am talking about it.

3.5.1 Negative Reciprocity and Trust

The Central Electricity Authority of India has reported that the grid loses 25 to 50 percent of the power it carries due to poor wiring and and theft, resulting in consistent blackouts and $17 billion in annual revenue losses (Katakey [2014]). This widespread culture of theft is potentially further exacerbated by a number of simultaneous factors, including well documented lack of confidence in public sector management of the power sector (Garg et al. [2016]), repeated failures by politicians to deliver on promises of free electricity made during short-term election cycles (Kumar et al. [2012]), very poor operations and maintenance and contract enforcement (Lee et al. [2016b]), and anecdotal evidence of hostility and violence that has broken out when distribution company security forces show up in large numbers to raid homes for illegal connections and enforce bill payment. An accumulation of such factors and compounding low confidence, satisfaction, (see Figure 3.3) and hostility over time may lead to low WTP driven by a cognitive mechanism of negative reciprocity (Fehr and Gächter [2000]) held by actors, which essentially implies an eye-for-an-eye vengeance philosophy of harming those who harm us. Under this behavioral hypothesis, poor villagers may want to punish government or private service providers by refusing to pay rationalized rates.[38]

Moreover, beyond just the issue of negative reciprocity, there may simply be a lack of trust, where consumers may not believe that the service will actually improve, regardless of what providers or politicians announce in the public sphere. Such a mentality could potentially be shaped by the historical precedence of poor fulfillment of electoral promises of universal and reliable electricity access.[39] As mentioned in the preceding socioeconomic section, one credible reason why older people may tend to have lower levels of

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[38] This situation can be viewed as somewhat analogous to another vein of literature related to tax morale and tax evasion, in which it has been argued that behavior around and beliefs about paying taxes is closely related to concepts of reciprocity toward the government (Luttmer and Singhal [2014]).

[39] For example, in an older study on water – which faces various similar challenges as electricity in LIDCs – Altaf et al. [1993] finds that WTP for systems with improved reliability was lower among households that were already connected with the piped water system, which led researchers to hypothesize that this might be the result of the households' historical experiences and general overall skepticism toward the system as a whole.

utility loss from a high frequency of outages (Ozbafli and Jenkins [2016]) is that they may be used to poor service and do not trust that it will improve. In addition, in another study, Abdullah and Mariel [2010] find that the level of trust in the electricity authority could account for variation in WTP values, while Townsend [2000] discusses the prevalence of lower WTP in countries with mismatches between price increases and improvements in service quality. Interestingly, however, a recent study on trust and WTP for reliable electricity conducted in Ghana found a reverse effect: individuals "who trust the government are currently not willing to pay more for an improved electricity service because they believe the promises made to them by politicians that they would be provided with an improved service without them having to pay more" (Amoah et al [2017]). Given the overall scarcity of evidence and research on the role of trust as a measurement for social capital and household WTP for improved electricity services, it is difficult to make a directional claim beyond the hypothesis that trust is an important determinant of household WTP for reliable electricity supply. On the one hand, negative reciprocity or a lack of trust in the government or relevant service providers can drive a low consumer WTP or even widespread theft/non-payment of bills. On the other hand, very high trust in governments can also drive a low WTP if the belief in political promises is strong. Such considerations may become even more complicated, when adding in dynamics such as cultural acceptance or rejection of private electricity provision and beliefs about what actors should bear responsibility for electricity provision (see Figure 3.3). Empirically testing such a hypothesis requires controls for and careful considerations of the potential confounding factor of general poor governance and enforcement of bill payment, which can foster a standard collective action problem.

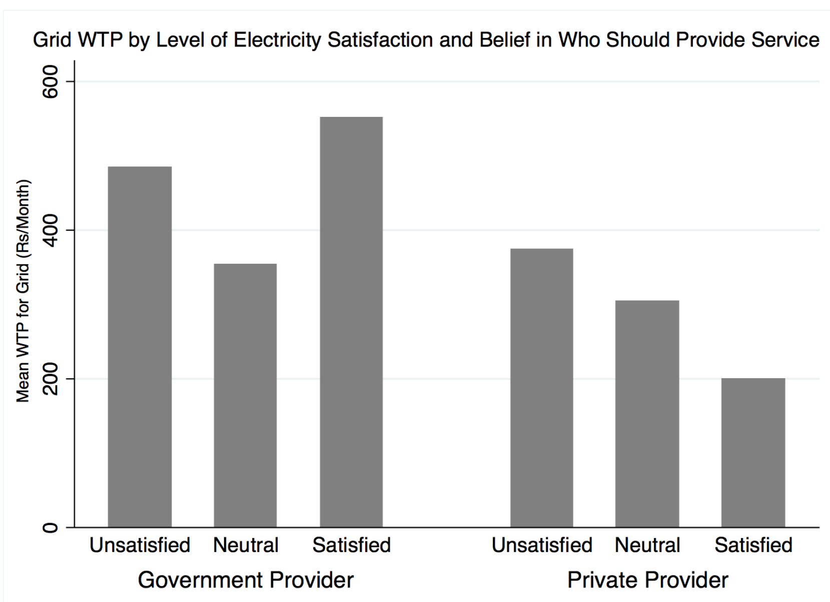


Figure 3.3: Mean WTP for the Grid (Rs/Month), according to consumers level of satisfaction with the electricity, as well as by their beliefs about what entities should be responsible for electricity supply (Source: Created using the Access to Clean Cooking Energy and Electricity (ACCESS) dataset (Aklin [2017]).

Even in the absence of empirical evidence, numerous service providers have anecdotally taken note of the prevalence of negative reciprocity in certain settings of electricity provision and the potentially enormous effects of mistrust on consumer WTP, thereby restructuring specific strategies to try and grow trust. Case studies on India, Kenya, and Brazil can be found in Box 3.1, Box 3.2, and Box 3.3. Such real-world approaches to addressing this cognitive phenomenon may provide important insights on effective means for reversing the trend, in complementarity with an increase in empirical research.

Box 3.1

Tata Power DDL: Working with Women to Tackle Electricity Theft in New Delhi's Slums

One of main causes of an annual ten-billion-dollar loss in revenue for India's power companies is the refusal of slum dwellers to pay their bills and the overall widespread incidence of electricity theft. When company officials try to enforce bill payment, they often face mobs and are beaten, tied up, urinated on, or even murdered. To address this longstanding social challenge, Tata Power Co.'s joint venture with the state government in Delhi created a model that is carrying beyond India in its effectiveness. In particular, in the early phase of piloting this model, TPDDL hired women who lived in 223 slums in the northern and northwest parts of Delhi to serve as local ambassadors for the company, calling them Abhas (which means light in Sanskrit). Today, this force has grown to 841 wives, mothers, and young women who "go around slums, knocking on neighbor's doors and persuading, coaxing, cajoling, and nagging them to pay their bills." As a last resort, if these tactics do not work and result in payment, then the power is disconnected. Over the last five years, this initiative has, at minimal cost, increased revenue by 183 percent and over 56,000 previously free-riding households became bill-paying, bonafide customers. Given that slum residents prefer to interact with women from their own communities, these Abhas have gained the support of community leaders: "the scarcity of resources in slums ensures an interdependence among residents that means they are more likely to listen to one of their own…the social fabric is much tighter in slum clusters…an outsider will never match up to having this level of influence."

Given the enormous success of this community capacity-building program, other rival companies have started to mimic the initiative in their own service areas. For example, BSES Delhi, which is a rival to TPDDL, worked with 40 women this year to pilot having the resident women distribute bills and collect payments from neighbors. The World Bank is now testing similar initiatives in Jamaica and Kenya, where challenges of electricity theft are also rampant, and is further considering expanding these pilots to other countries in sub-Saharan Africa.

Source: Shrivastava [2017]

Box 3.2

Condesa Slum Electrification: Community and Trust-Building in Nairobi, Kenya

In just one year, Kenya Power went from only 5000 to 150,000 households gaining formal electricity connections, largely as a result of a number of core community-based initiatives. In particular, two main approaches accounted for a significant portion of this turnaround in the company's operations:

1. First, Kenya Power adjusted its business model to undertake more of a community-based approach in the slums, which involved working with local community members and leaders to market the benefits of legal connections (such as safety, reliability, and affordability). Moreover, Kenya Power decided against applying a punitive approach, which meant they no longer took down illegal connections and rather tried to educate consumers on the benefits of legal connections.

2. Second, Kenya Power strengthened its collaboration with the Kenya Informal Settlements Improvement Project, which is a World Bank supported program that holds a strong reputation in the urban slums. By creating strong connections with local partners, the company was better able to segment the slum areas and create more targeted and area-specific approaches.

As a result of this approach, many of the former vendors of illegal electricity have now joined the legal business of selling Kenya Power chips to consumers, who largely use a pay-as-you-go scheme, and save more money than what they used to for illegal electricity.

Source: World Bank [2015]

Box 3.3

Light: Rebuilding Trust in the Favelas of Rio de Janeiro, Brazil

In the last several decades, a number of the favelas of Rio de Janeiro have become overtaken by the drug trade and drug lords who carry out territorial practices, preventing residents from accessing basic services, such as water, sanitation, healthcare, or energy. In particular, with regards to energy access, residents have often had to turn to other means to obtain access, including stealing directly from overhead cables. This pervasive practice of electricity has caused Light, the fourth largest Brazilian power company in terms of client base, to cope with 64.1 percent non-technical losses and 90.4 percent default on bill payment. Light faced an environment of weak social contracts and a complete lack of mutual trust between the power distribution company and the population of the favelas. Consequently, the company, in partnership with the federal government, took a multifaceted approach to try and reverse this unsustainable trend.

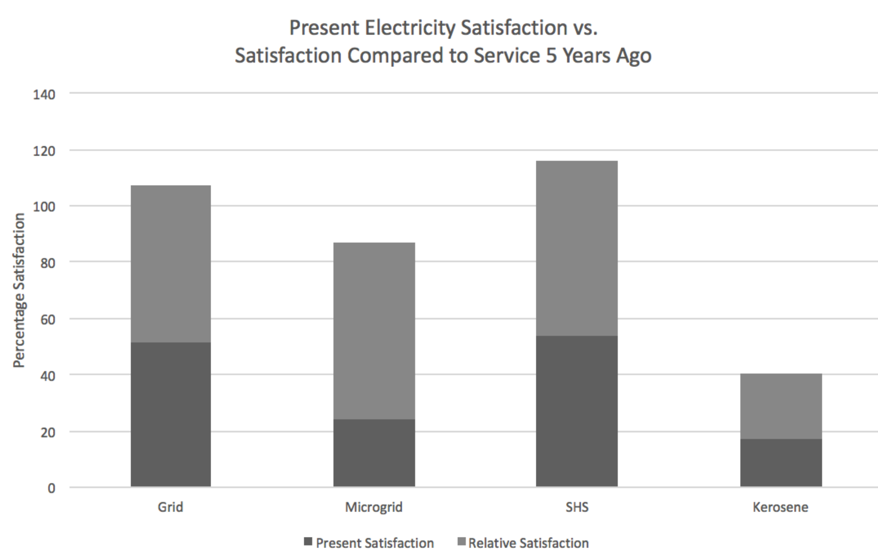
First, Light worked with the federal government to establish regulatory incentives targeted at improving the affordability of energy bills and also invested in the development and installation of new electricity measurement equipment that aimed to overcome future theft from the overhead cables. Second, the company invested resources in rebuilding the broken social contract with the consumer base, including providing more efficient and cheaper home appliances, curating economic and social opportunities, entrepreneurship training, and access to micro-financing. As a result of these actions, the average level of non-technical losses and default in these areas have dropped spectacularly to 11.1 percent and 1.5 percent, respectively. Moreover, the company has implemented other recent multi-system innovations, such as recycling waste in exchange for discounts on electricity bills. This multi-systemic and holistic approach to rebuilding trust in a community in which it was formerly broken has been highly effective in transitioning the company toward a sustainable and successful business model.

Source: Lins [2014]

3.5.2 Reference Dependence and Status Quo Bias

An alternative, or perhaps additional, potential explanation for the low WTP for reliable electricity could be the prevalence of reference dependence, or related mechanisms such as status quo bias (Kahneman and Tversky [2013]). Reference dependence, which is arguably one of the most fundamental principles of prospect theory, describes the state in which people can evaluate outcomes relative to a reference point, and then classify gains and losses according to that anchored reference point. This is rather similar to the notion of loss aversion, which was presented earlier in this essay. Similarly, status quo bias describes a condition in which the current baseline (i.e. the status quo) is taken as a reference point and any change from that baseline would be perceived as a loss. Such cognitive biases can be important to consider in the context of rural electrification when evaluating approaches for changing the consumer psyche and mindset about paying for electricity closer to what would be considered the cost-of-service rate, or in some cases, paying at all. For example, agricultural and residential consumers in India are arguably accustomed to receiving poor quality electricity at a low price and may therefore be averse to increases in prices and view them as unfair. In addition, some sets of surveys suggest the existence of what analysts refer to as an “entitlement-minded" attitude among some electricity consumers (TERI [2017]), where the “expectation of the continuation of certain government benefits is relatively common in contexts where social protection systems are less well developed or where benefits such as energy subsidies are seen to be part of a long-standing social contract" (Garg et al. [2016]). On the other hand, consumers may also be so accustomed to the status quo of poor, unreliable access and may harbor pessimism that the situation will change or improve, which may bias a preference for the current baseline (i.e. not paying, paying well below the cost of production, or theft) as reference point. For example, as previously introduced, in a recent study conducted in Nigeria, Oseni et al. [2017] finds that age is negatively related to the probability of a household to engage in self-generation, suggesting that “older people were more likely to grow up without electricity, and may have adapted to unreliability and found it more normal to live without [good] electricity."

Figure 3.4:
Percentage of Respondents Satisfied with Electricity Now vs. Overall Satisfaction Compared to 5 Years Ago



Source: Created using the Access to Clean Cooking Energy and Electricity (ACCESS) dataset (Aklin [2017])

Even a basic descriptive examination of survey data on consumer satisfaction with their electricity services in India reveals interesting time-dependent responses and attitudes. Using the same ACCESS dataset as before, Figure 3.4 above portrays curious differences between the percentage of respondents who are satisfied with their electricity, when asked about it in the present tense, as compared to when they are asked about their satisfaction relative to the service they experienced five years prior, with most individuals showing a more positive response when asked to compare to the past – even though both report generally low satisfaction overall. In general, very little is known about the ways in which temporal behavioral biases such as loss aversion (reference dependence) and consumer myopia affect energy behavior (Hahn et al. [2016]), particularly in developing contexts. Consequently, this second hypothesis contends that an entitlement-minded attitude or a bias toward the status quo decreases consumer WTP for electricity, or rather prevents any changes to their current below cost-of-service WTP.

3.5.3 Information or Inattention Biases

A final set of cognitive biases that are worth considering for their effects on consumer behavior and WTP in resource constrained settings are information and inattention biases. In cognitive psychology literature, an information bias could be classified as a form of bias that involves a distorted evaluation of information. Similarly, in the economics literature, attentional bias is defined as the amount that an individuals' preferences deviate from his/her preferences under full information. Thus, if consumers are well informed, they will have little or no attentional bias or have little bias if they do not care about the information they learn. For example, in a relatively recent study, Allcott and Taubinsky [2015] probe this question about the magnitude of inattentional biases, if any at all, as it relates to low consumer adoption and willingness-to-pay for CFLs in the United States. An additional cognitive bias that is closely related to this discussion that is worth mentioning is mental accounting, which is a set of cognitive operations that individuals use to organize and keep track of financial activities within their minds, which can often lead to irrational spending and investment behavior (Thaler [1985]). There are a number of potential parallel occurrences of such biases in the context of rural electrification in India and other MIDCs and LIDCs, namely misinformation about subsidies, as well as a lack of information or rational mental accounting on the relative losses that consumers incur in the status quo situation.

Misinformation about Subsidies:

In a recent study, Bringeus and Karlsson [2016] found a clear positive relationship between awareness about the existence of electricity subsidies and support for price reform. Furthermore, in a set of attitude and perception surveys conducted in the state of Rajasthan, Garg et al. [2016] found that citizens are generally considerably unaware or misinformed about the current financial status of distribution companies, and only half were aware about the existence of subsidies.[40] These findings point at the potential presence of widespread inattention or misinformation about the magnitude of government support already provided to discoms and begs the question of how more accurate, full, or locally accessible provision of information about subsidies and costs could affect consumer perception of service providers and their willingness-to-pay. Moreover, given the rise of pre-paid or smart metering technologies that include in-home displays providing feedback on consumption and usage (Jack and Smith [2016], Lee et al. [2017]), there are important questions to consider about the role that such technologies can play in reducing such information gaps, and affecting subsequent behavior. For example, in one of the few studies that has thus far examined this question, Pellerano [2015] conducted a large-scale randomized experiment in Quito, Ecuador to study the effects of information interventions –such as increasing the salience of price notches in the tariff structure – on residential consumption and conservation behavior. While there is some work arguing that there is little causal evidence that information interventions or salience features of smart meters change behavior or consumer decision- making (Allcott and Sweeney [2016], Buchanan et al. [2015]), most of these studies have been confined to geographies without access or reliability deficits, thereby calling into question the external validity of such conclusions in opposite settings. This thesis posits that misinformation about subsidies and other pricing components of electricity access places a downward bias on consumer WTP for reliable electricity services.

Inattention or Lack of Information on Relative Losses Incurred in Status Quo Situation

An additional conceivable mechanism embedded within this hypothesis is the possibility that households are unaware of or have imperfect information about the long-run benefits and cost-benefit ratio of modern and reliable electricity services or solar-based power provision (Lee et al. [2016b]). In the current situation of unreliable access, it is common for households to turn to substitute backup diesel generators or kerosene – which come with various forms of costs, such as time spent to obtain substitutes, negative health effects, and ensuing longer-run effects on labor and productivity. For example, a very recent study conducted in Nigeria found variability in the WTP of households that had back-up self-generation supply sources, as compared with households that did not (Oseni et al. [2017]). Therefore, direct information about the benefits of reliable, safe, and formal electricity access could hypothetically influence consumers WTP. While there is, to the best of my knowledge, an absence of experimental and empirically robust evidence on the impact of interventions specifically addressing this bias, there are some informative anecdotal cases that imply positive influence on WTP. For example, as mentioned in Box 3.2, employees at Kenya Power worked directly with community leaders in the Condesa slum in Nairobi to effectively market the benefits

[40] 32 percent of households believe distribution companies could cover their costs entirely by customer revenues, 54% of households believe costs are covered through a combination of revenues and government support, and of this 54 percent, 55 percent believes the government provides <20 percent of total costs, (whereas the actual figure is closer to 50 percent of total costs) (Garg et al. [2016]).

of legal connections, such as safety, reliability, and relative affordability, as compared to illegal connections, resulting in a huge increase in legal connections (World Bank [2015]). Moreover, in an interview in July 2017 in Bihar, India, employees at Husk Power, a biomass and solar micro-grid company, discussed a consumer engagement strategy that involves carrying out safety and educational workshops and information sessions with households in order to overcome information gaps, and subsequent potential for a lack of trust. In spite of the limited research on this behavioral determinant, it is nonetheless important to consider and further examine given uncertainties in information about how accurately household considerations of trade-offs affect their WTP. In sum, this final hypothesis puts forth the claim that misinformation and attention-based cognitive parameters decrease consumer WTP for reliable electricity services.

3.5.4 Preliminary Conclusions and Future Behavioral Work

What can be taken away from these behavioral insights and hypotheses with regard to their interactions and effects on consumer WTP? At this current point in time, it is very difficult to make any causal claims, especially in light of the absence of many studies in low income and developing countries. Moreover, there is almost an undeniably high likelihood that many of these cognitive biases occur simultaneously and further reinforce one another, with additional influence from the socioeconomic and demographic variables, making it challenging to assess individual effects of these biases on consumer behavior, preferences, and decision-making. At the same time, however, useful insights have emerged from practitioners spending time in the field and observing patterns of human behavior, with many of these anecdotal studies implying that notions of trust, reciprocity, reference dependence, mental accounting, information, and awareness all, to some extent, play a decidedly important and determinative role in shaping attributes related to consumers' WTP electricity access and reliability across electricity modes. Given that the intersection between behavior and electricity access in LIDCs is very rapidly gaining traction among researchers (see Table 3.4 for a sample of recent evaluations registered under the American Economic Association), it is probable that more causal findings and implications will emerge in the coming years, thereby shaping more valuable and effective strategies for planners and businesses operating in the space of energy access. While I will expand a bit on these points in the next two chapters of thesis through case study analyses and policy recommendations, here, specifically, I will lay forth a preliminary research proposal that aims parse out any simultaneity of behavioral biases and isolate effects on WTP. Thereafter, the next section will transition into a more in-depth discussion on electricity reliability and technical determinants of consumer WTP.

Research Proposal for Future Work

The preliminary proposal that is presented here as a suggestion for future work is structured as priming[41] and informational intervention-based randomized controlled trial that is comprised of three phases: (1) a pre-experiment survey, (2) randomization into separate information treatment arms, and (3) post-experiment contingent valuation and assessment of WTP for reliable electricity access from an existing utility that is ideally a partner on the project. While the first phase essentially aims to gather baseline demographic information and pre-intervention preferences and beliefs about electricity services and the service provider, the bulk of the more profound insights are embedded in the second and third phase. In particular, in the second phase of the experiment, subjects will be randomized into one of six possible information treatments, as well as a control group that receives no information intervention. The subjects will be told in advance that the partnered utility company (or perhaps a hypothetical new utility) would like to gauge their WTP for reliable electricity access, but prior to completing a contingent valuation exercise, they will be presented with some information to consider. Participants will not be aware of the differences between the information treatment arm they get assigned to in order to prevent potential spillover effects between treatment groups:

a. **Treatment A: Reciprocity toward Service Provider**

In this information treatment, subjects will be further randomized into two sub-treatment groups, namely positive reciprocity-oriented and negative reciprocity-oriented. The subjects provided the positively-primed information treatment will read some variation of the following passage:

Our trustworthy Government of India, state utilities, and service providers work tirelessly to fulfill their mandate to provide reliable 24x7 electricity access to all the citizens of this great country. As per the 2006 rural electrification policy, we have reached 100% electrification of villages and fulfilled this government promise. We are further working on 100% HH electrification and have set up a web portal, GARV, to show real time data on our progress in reaching this goal and helping our citizens have high quality, reliable power to lead productive lives. Citizens will be guaranteed sustainable operation and maintenance services and accessible grievance redressal mechanisms.

In contrast to the favorable tone of this passage, which is meant to prime a sense of positive reciprocity, the negative information treatment will read some variation of the following passage:

While the Government of India, state utilities, and service providers have promised to provide 24x7 access and claim to have electrified 100 percent of villages, more than a third of rural households are still in the dark and lack access. Politicians have promised to give the neglected and poorest citizens reliable access for years and consistently fail to deliver on this promise. When materials or systems are in need of repair, it is rare for anybody to show up to fix the problem. However,

[41] In psychology research, priming is a technique in which exposure to one stimulus can influence the response to a subsequent stimulus, without conscious guidance or intention. With these information-based interventions, the wording in each category is meant to prime the respondent and trigger the underlying cognitive bias, and thereafter assess the ways in which this may affect their post experiment WTP valuation.

service providers show up in droves to enforce bill payment.

b. **Treatment B: Reference Dependence**

In this treatment arm, subjects will be prompted to consider the financially unsustainable, yet customary practice of low cost or free power provision and is meant to prime subjects to consider the longstanding tradition of free and unmetered power provision, in particular in the agricultural sector.

Under the former Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) rural electrification scheme launched in 2005, households and citizens living below the poverty line and farmers are supposed to receive free and/or highly subsidized electricity connections. Cross-subsidization policies between above-poverty-line (APL) and below-poverty-line (BPL) households are fairly standard and common in countries with successful rural electrification programs.

c. **Treatment C: Misinformation about Subsidies**

Next, in the fourth possible information treatment, participants will be provided the following text to consider. This prime aims to provide accurate data about the current levels of government support to distribution companies, which may come as a surprise to the average participant who is generally misinformed and largely underestimates existing levels of subsidies (Garg et al. [2016]).

The Government of India already provides a sizeable level of subsidies and financial support to distribution companies, helping to prevent even higher tariffs for customers by enabling the utilities to more effectively cover their costs. In fact, the Government of India supports about 50 percent of distribution companies' operating costs, in the form of direct transfers, state bonds, and other bailouts.

d. **Inattention or Lack of Awareness on Relative Losses Incurred in Status Quo**

For the fifth information treatment participants will be presented with some statistics that aim to catalyze internalized considerations and potentially misinformed mental accounting about the costs and benefits of modern electricity services versus the current patchwork of means by which many poorer citizens fulfill their lighting and cooking needs (i.e. kerosene, back-up diesel generators, fuel wood, etc.):

Reliable electricity access will provide citizen with extra hours of the day to spend on productive and income-generating activities, rather than on collecting fuel-wood or paying for kerosene. The costs associated with paying for reliable power and switching from the accustomed fuel sources are far outweighed by benefits of better quality lighting, improved safety, reduction in indoor air pollution and improvement in health, greater convenience, and an associated sense of progress and improvement in social status, among many other forms of value derived from paying for reliable electricity access over the status quo situation.

e. **Credit Constraints and Convenience of Payment**[42]

Finally, in the ultimate information treatment arm, participants will be presented with information about a convenient mobile-based or localized payment scheme that ostensibly aims to make bill payment easier for the poorest households:

Electricity access is among the highest priorities for most citizens. However, energy also constitutes a relatively large portion of household income. Fortunately, the rise of mobile phone usage has enabled the design of very convenient payment schemes that make clients' lives easier and allow them to make payments in small-intervals in a way that takes income constraints into account. Service providers in India are exploring the usage of pre-paid electricity meters for households, which can be topped up through mobile phones. This will automate the system and payments more manageable for citizens.

As previously mentioned, the control group will receive no information treatment or passage to read prior to completing the contingent valuation exercise in phase three of the experiment. The approach that is arguably best suited to evaluate WTP in this research proposal will be the dichotomous choice format (discussed under the Contingent Valuation Methodologies section of this essay), which is a generally preferred method since it reduces cognitive load for respondents and generally mimics peoples' behavior and decision-making in regular markets (FAO [2000]). Under this method, respondents will be asked if they would pay 'X' INR (rupees) per month to obtain reliable electricity services from the partnered utility or a hypothetical new utility and there will only be two options: yes, or no. The INR amount will be varied across the respondents and fall somewhere in the range of a rate the utility will need to charge to have financial viability over a certain desired period. The results from the participants in all the treatment arms and control arm will be modeled with a likelihood function on the interval data and an ordered probit regression model.

Ultimately, this proposed RCT experiment aims to investigate and partition the potential ways in which underlying cognitive mechanisms may adjust the internal and external attributes that shape consumers' WTP and personal "utility" valuation of electricity access and reliability across technology options. Better understanding and diagnosis of the fundamental motivations and perceptions that end-users may hold could help policymakers and electricity distribution business actors in prioritizing and designing cost-effective interventions or programs that would best address the key constraint(s) that preempt progress in this dimension of rural electrification. This information may, in the end, help to generate actual demand for better services, foster improvements in bill payments, improve the financial health of the sector, and gradually turn the negative feedback loop in a reversed, positive direction.

[42] This information treatment intersects more with the constraint of ability to pay or "affordability" which will be discussed a bit later in this essay.

In the next section that continues to build a more comprehensive understanding of consumer WTP and decision-making parameters, I turn to a deeper discussion of electricity reliability – an issue that has thus far been discussed widely throughout this thesis but only at a high level – and technical determinants of WTP.

Table 3.4: Randomized Controlled Trials on Energy and Behavior in AEA Registry

Cognitive Bias	Country	Proposal Description	Status	Source
Information	NA	This proposal, titled "The Welfare Effects of Information Nudges," studies biased beliefs about the benefits of energy efficient lighting, constructing two different informational nudge interventions to study their impacts on welfare.	Ongoing, Started March 2018	Lorenz et al [2018]
Information	Australia	This proposal, titled "Simplifying energy fact sheets to improve consumer understanding," is structured to study how and if customized and user-friendly fact sheets improve consumer comprehension, clarity, and decision-making on their household energy choices.	Completed, November 2017	Shea [2018]
Information	Senegal	This proposal, titled "Senegal Solar Lights Quality Assurance and Guarantee Impact Evaluation," aims to better understand consumer behavior and difficulty differentiating between good and bad quality technologies. In particular, the study proposes to test whether pilot informational interventions help close information gaps and increase demand for higher quality products.	Started, March 2018	Coville and Reichert [2017]
Awareness	Senegal	This proposal, titled "Senegal Behavior Change and Solar Lights Evaluation," aims to carry out a behavior change campaign that relies on a combination of radio clip broadcasting and community outreach on per-capita cost savings to assess effects on consumer awareness, understanding, and demand for solar lighting.	Completed, May 2016	Coville and Reichert [2017]
Attention	Kenya	This proposal, titled "Behavioral determinants of household energy efficiency in a development context," aims to study how limited attention, product uncertainty, and mental accounting affect consumer perceptions of energy saving and technology adoption. In particular, the study includes two interventions: (1) encourage consumers to have a greater level of attention by calculating expected savings from an energy-efficient appliance and (2) randomize access to a trial appliance for a week before making purchasing decisions.	Started, November 2017	Berkouwer and Dean [2017]
Information	Namibia	This proposal, titled "Improving Payment Behavior for Water in Rural Namibia," while specifically relevant to water, has many parallels to the energy sector in LIDCs. In the first stage of the project, the researchers are analyzing a data panel on payment behavior of private customers in the rural areas of the country. Next, the researchers conduct telephone interviews to better understand reasons for non-payment and then will pilot targeted SMS messages to test two behaviorally informed interventions around building consumer commitment strategies for	Ongoing, Started November 2014	Rockenbach et al [2015]

		payment.	

Source: Author Compilation, 2018 and American Economic Association (AEA) RCT Registry [2018])

3.6 Technical Determinants of WTP for Electricity

…Next, you step into the office of MSEDCL, the electricity company, to sign up for a power connection to your new house. The salesman offers you a choice of three plans, each with its own Bata-style price. Plan A: power supply at Rs 5.95/kWh with a reliability of 98 percent and with a voltage variation of +/- 6 percent, Plan B: Rs 7.95/kWh, with a reliability of 99.98 percent and no voltage variations, Plan C: Rs 9.95/kWh which is the same as Plan B, but with the additional feature that 20 percent of power will be sourced from plants that use clean and renewable energy. Ok, just kidding. No utility offers such a choice yet (except Mumbai, where a reliability surcharge is levied). But the point to be understood here is that 'electricity' is not a single product, even if the basic idea of moving electrons remains the same. There can be many 'sub-products' depending on the reliability and quality standards desired (Rajagopalan [2015]).

A set of interactions in analyses pertaining to rural electrification whose causal relationships and dynamics in different contexts continue to be poorly understood is that of WTP, ATP, and reliability of power. While the discussions and analyses in the previous section placed a greater level of focus on the socioeconomic, demographic, and behavioral explanatory factors behind variability in consumer attitudes, preferences, and WTP, this section places a greater emphasis on the technical components of this persistent puzzle. As alluded to in the passage above, which is excerpted from an article called "What is the real cost of unreliable power supply," electricity reliability and its subsequent social, economic, and psychological consequences is by no means a simple issue. Following from this spirit of complexity, I begin to try and probe the research question: what are the effects of different forms of reliability,[43] across both grid and off-grid electricity supply technologies, on consumer WTP for *reliability*, as well as other measures of welfare? Before diving into a discussion on the current state of knowledge around this question, I will first introduce a number of the different ways in which reliability is measured, as well as present a closely related notion called the Cost of Non-Served Energy, which I will refer to as CNSE from this point onward. Thereafter, I will, similarly to the previous section on behavior, present a brief research proposal for future work, which will integrate some of the capabilities of the Reference Electrification Model.

3.6.1 Technical Measures of Reliability: SAIFI, SAIDI, CAIDI, and MAIFI

Reliability, as it is currently understood on a more universal technical level, is defined in a number of different ways and incorporates several key aspects, such as the number of customers, connected load, the duration of the interruption measured (in seconds, minutes, hours, or days), the amount of power (kVA)

[43] Reliability can be measured and understood in a number of different ways, with varying technical definitions. This will be discussed in further detail.

interrupted, and the frequency of interruptions. The four most common indices for measuring reliability, as defined in the IEEE Standard 1366 include SAIFI, SAIDI, CAIDI, and MAIFI:

a. **SAIFI –** or System Average Interruption Frequency Index, is the average frequency of sustained interruptions per customers over a predefined area.

b. **SAIDI** – or System Average Interruption Duration Index, is the sum of the restoration time for each interruption event and divided by the total number of customers.

c. **CAIDI** – or Customer Average Interruption Duration Index, is the average time needed to restore service to the average customer per sustained interruption.

d. **MAIFI** – or Momentary Average Interruption Frequency Index, is the number of momentary interruptions (that result from each single operation of an interrupting device) divided by the total number of customers served.

While these indices are informative on a technical level, there are nonetheless many debates about how comparatively they can be used across geographies with immense social differences that can affect interpretations of the inputs and outputs of calculations (Kueck [2005]). For example, Harish et al. [2014] argues that such conventional measures fail to monitor reliability in the holistic ways that are necessary in the rural Indian context, as well as in other LIDCs, where outages (scheduled and unscheduled load shedding) are caused by a mixture of complex demand side, local capacity, and political economy factors (Gertler et al. [2017]). Figure 3.5, which draws from the well-known Afrobarometer Survey conducted across 36 countries in Africa, serves to illustrate these points about the complexity and nuance of the interface and tensions between access and reliability in LIDCs, and, similarly, Figures 3.6A-B demonstrate variability in consumers' source of dissatisfaction with electricity services across connection types in India, including issues with electricity availability and quality. Moreover, the Government of India currently lacks any defined right to a reasonable availability of supply, only providing a vague target of 6h/day, which "means little if supply does not correlate to times of demand" (Harish et al. [2014]). Each of these measurements and the reliability definitions that they register – from frequency of outages, duration of outages, and restoration wait time – may manifest differently into the consumer psyche and subsequent WTP and decision-making. For example, even if outages are frequent, consumers may be WTP more if they are guaranteed short durations or quick restoration times. Or, in contrast, even if the duration time of an outage is long, consumers may be WTP more for electricity if they are informed well in advance in order to manage their own expectations. This variability in consumer preferences and WTP for reliability across its different forms of measurements is not well understood and a highly valuable area of future research. An India-specific dataset that future researchers may take interest in within this context is ESMI or the Electricity Supply Monitoring Initiative run by Prayas Energy Group. Please refer to Box 3.4 for more details.

3.6.2 Social Measures of Reliability: Cost of Non-Served Energy (CNSE)

Before moving onto an analysis of the state of knowledge around reliability of power and WTP in LIDCs, another metric that needs to be considered is the CNSE, a complex concept that was briefly touched upon in the beginning of this essay and that generally represents the loss of utility (cost) incurred by consumers when there is no electricity at the time of intended use (Borofsky [2015]). This measurement is also sometimes referred as Value of Lost Load or VOLL. Within the Reference Electrification Model, the CNSE is designated by two separate values, namely one for so-called essential or critical loads and the other for non-essential or non-critical loads. In theory, the CNSE value or utility loss for an essential load should be greater than that of a non-essential load. There are a number of ways in which to estimate these values, including costs of alternatives and "substitutes" (such as kerosene and other forms of self-generation) that may be used to cope in circumstances of power loss. Ultimately however, these substitutive measurements are generally woefully inadequate at capturing the huge level of subjectivity that is inherent in this metric for welfare loss. Nonetheless, the CNSE, when combined with the various definitions of

Box 3.4

"Watch Your Power" or the Electricity Supply Monitoring Initiative (ESMI)

Electricity consumers in India very often encounter poor quality electricity supply, facing frequent interruptions, load shedding, blackouts, and low voltage levels, resulting in widespread investment in coping mechanisms such backup diesel generators and voltage stabilizing devices. In fact, it is estimated that consumers have to spend several thousands of crore rupees annually to address challenges with unreliable electricity supply, which is most prevalent in peri-urban and rural areas of the country. In spite of this pervasive problem, there is a dearth of temporal and spatial data on its occurrence, making it difficult for consumers and other stakeholders to monitor supply quality and hold distribution companies and utilities accountable for their performance.

The ESMI program of Prayas Energy Group, based out of Pune, was created to contribute to overcoming this challenge. In particular, the group has installed several hundred Electricity Supply Monitors (ESM) in households, farms, and small commercial establishments throughout the country, which record voltage by the minute at the location of installment and transfers the data to a central server, which is made publicly available on watchyourpower.org. Consumers and civil society organizations, as well as researchers and regulatory commissions, can use this data to verify if the villages electrified through India's rural electrification program actually receive their mandate of 6 hours of daily supply and to compare supply quality in different regions of the country and assess any potential biases in supply interruptions and quality. Given that this problem exists across many countries, Prayas is currently partnering with the World Bank and other organizations to pilot similar programs in Indonesia, Tanzania, and Kenya.

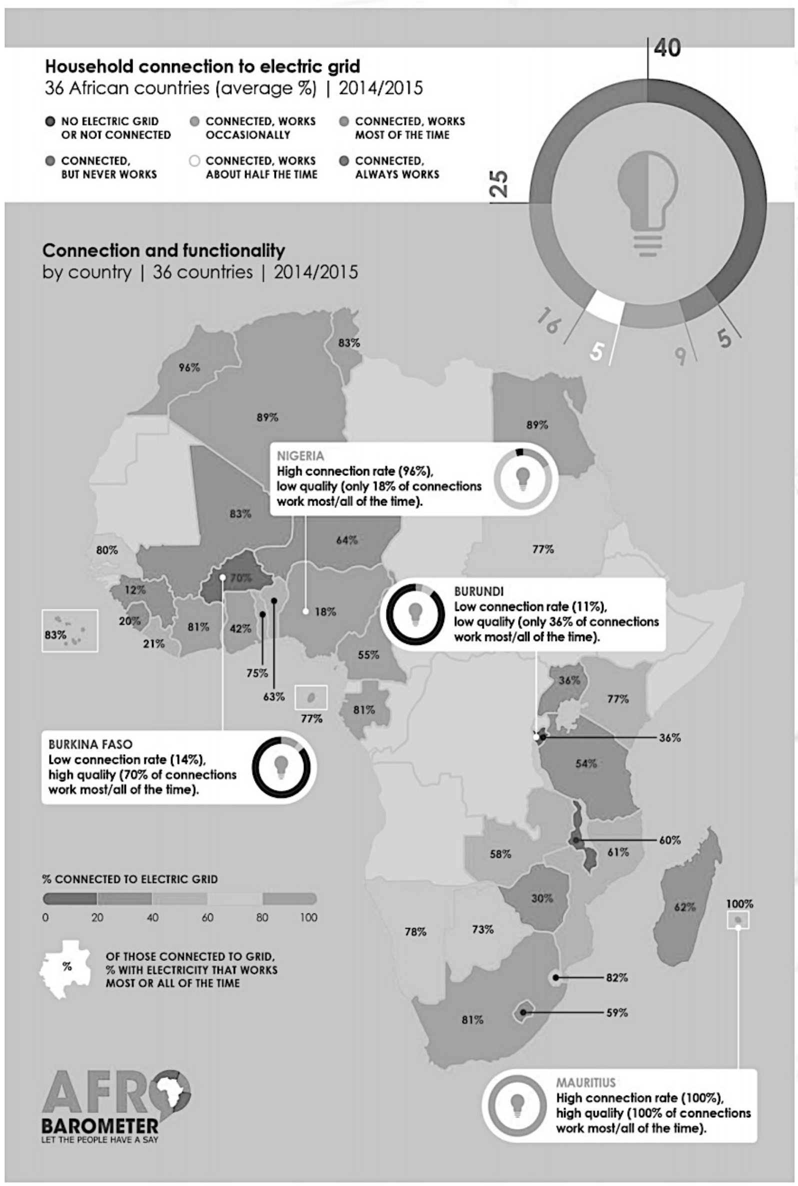
Sample Data from January 2018 Analysis Report:

In January 2018, 52 percent of ESMI locations experienced outages for 15+ hours, 35 percent of ESMI locations experienced over 30 interruptions each over 15 minutes long, and 28 percent of locations experienced average daily outages of 30 minutes + during evening hours.

Source: Prayas Energy Group, ESMI [2018]

reliability, as well as insights on socioeconomic, demographic, and behavioral parameters, can serve as a useful tool for assessing trade-offs in consumer decision-making. While the passage at the beginning of this section joked about a hypothetical cocktail of options that a consumer can face, such a reality may not be so distant in the future. Measurements such as the reliability indices and a more expanded definition of CNSE can be used to effectively assess and communicate these trade-offs and options to consumers so they can make the most informed choices. Overall, a stronger comprehension of the trade-offs associated with decisions around electricity reliability, financial constraints, appliance ownership and aspirations, and differential lifestyles and priorities is not only important for the ways in which it can improve predictions about consumer behavior but also better informs welfare-enhancing policies and discourse around the grid and off-grid systems in resource constrained settings (Graber et al. [2018]).

Figure 3.5: Variability in the Meaning of Reliability of Access in the Continent of Africa



Source: Oyuke et al [2016]

3.6.3 State-of-Knowledge on Reliability and WTP for Electricity

Now that the definitions of reliability have been established from multiple angles, what is the actual current state-of-knowledge with regards to its effects on WTP for both reliable electricity services and baseline electricity access? At this point in time, there are very few published studies that have examined attributes influencing WTP for reliable electricity in the specific context of LIDCs (see Table 3.5 for a summary of these studies), with most existing papers rather focusing on WTP for "green" energy attributes in high and middle-income countries (Goett et al. [2000], Hensher et al. [2014]). Moreover, of the few studies that have examined different effects of poor reliability and power outages in low access settings, most have focused on firm-level, rather than household-level, impacts (Steinbuks and Foster [2010], Fisher-Vanden et al. [2015]). As discussed in Lee et al. [2017], "[there is currently] almost no data on even the most basic patterns of outages in developing countries...we need more research on the economic consequences of different levels of power quality, as well as the potential gains from investing in improvements" at both a firm and household level.

In spite of the general dearth of studies, the nascent and growing literature nonetheless points at a number of interesting findings that serve as starting points to an expanding the research on these topics. For example, three studies carried out throughout India present a significant relationship between electricity reliability, demand, and WTP: Khandker et al. [2012b] finds that a one hour increase in average availability of electricity at the village level increases the rate of household electricity adoption and electricity consumption by 2.4 percent and 14.4 percent, respectively. Moreover, in one of the few studies in India that used choice experiments and contingent valuation methods to analyze consumer responses to different outcome measures for reliability in Madhya Pradesh, Gunatilake [2012] found a WTP (per month) of 106Rs for 24-hours of electricity supply (as compared to 38Rs for 12 hours); 243Rs for the highest quality of service; 38Rs for improved customer service; and 45Rs for accurate billing practices. This greater appetite and WTP for increased reliability extends to the off-grid space as well: in a study carried out in Uttar Pradesh, Graber et al. [2018] find that consumers who have been exposed to microgrids report, at a very high level of statistical significant (t=2.43), a greater satisfaction with reliability as compared to consumers exposed to both the grid and microgrids simultaneously; have a higher WTP for reliability attributes; have a higher WTP for electricity that is delivered when expected, rather than for 24 hours of electricity; and generally place a higher value on electricity that is reliable during evening hours. Similar conclusions to the studies conducted in India have been found in analyses and surveys implemented in a number of countries in sub-Saharan Africa as well. For example, in a recent project carried out with households in Nigeria, Oseni et al. [2017] find that engagement with self-generation is positive correlated with WTP for reliability and that households are more concerned about the total length of outages (outages time) than the separate impacts of outages frequency when making WTP decisions. In a set of very analogous studies, Taale and Kyeremeh [2016] find that prior notice on outages is positive correlated with WTP for reliable electricity in Ghana and Abdullah and Mariel [2010] use contingent valuation methods find a WTP for 50KSh to avoid outages among households in rural Kenya.

In a parallel vein of literature, there is a rising interest in analyzing the intersections of the different forms of unreliability and varying impact each can have on consumer psyches. While such behavioral attributes were not studied explicitly in the aforementioned studies, the findings on a high WTP for prior notice on outages and their duration arguably indicate a high value that is placed on expectations: households want to be able to perceive and mentally prepare for outages before they happen, such that they can manage and mitigate their actions effectively around the outage. Following from this line of thinking, in a very compelling new study conducted in Indonesia in areas where the grid is unreliable, the authors find that users felt that they experienced a higher unavailability of power than the SAIDI and SAIFI values reported by the utility. As a result, Reinders [2018] proposed new indices called the Perceived (P) SAIDI and SAIFI, which are based on the perceived frequency and duration of blackouts experienced by users and are considerably different from the utility-reported values. Such variability in consumers' memories and cognitive perception in areas in which a lack of reliability occurs so often as part of day-to-day life may bear important consequences for their WTP (and similarly, for their utility, satisfaction, and welfare, as discussed in the beginning of this essay). Ultimately, there is a great deal of research that is necessary for continuing to build a better picture and understanding of the relationship between reliability and consumer preferences and attitudes that interact with the utilitarian, social, and hedonic attributes of their WTP, particularly in off-grid spaces as well rather than just on the grid. In order to add to this momentum, in the following section, I present a basic research proposal on a choice experiment that utilizes capabilities of the Reference Electrification Model.

Table 3.5: Existing Literature on Technical Parameters Affecting Consumer WTP

Supply Source	Country	Important Attributes	Urban/Rural	Source
Grid	India	General availability of electricity increases HH adoption by 2.4 percent.	Rural	Khandker et al. [2012b]
Grid	India	Higher WTP for 24-hours of electricity, highest quality of service, improved customer service and maintenance, and accurate billing practices.	Rural	Gunatilake [2012]
Microgrid, Grid	India	Higher WTP for reliability attributes, electricity that is delivered when expected (rather than 24 hours), and electricity that is reliable in the evening.	Rural	Graber et al. [2018]

Grid	Nigeria	Higher concern about total length of outages (outage) time than separate impacts of frequency and duration when making WTP decision.	Rural	Oseni et al. [2017]
Grid	Ghana	Prior notice on outages positive correlated with WTP.	Urban	Taale and Kyeremeh [2016]
Grid	Kenya	High WTP for avoidance of outages.	Rural	Abdullah and Mariel [2010]
Grid	North Cyprus	Willingness to face 3.6 and 13.9 percent increase in monthly bills in summer and winter to avoid outages.	Urban	Ozbafli and Jenkins [2016]

Source: Author Compilation, 2018.

3.6.4 Contingent Valuation Experiments for WTP and Reliability Using REM

As discussed in the previous essay, the Reference Electrification Model or REM is a technoeconomic optimization software that has been developed and grown through several generations of students in a joint research initiative between the MIT Tata Center for Technology and Comillas Pontifical University in Madrid. This model utilizes information about areas with poor electricity access to determine the best electrification mode (namely grid-connected, micro-grids, or isolated solar systems) for each household or other load center, estimates cost and electricity demand, and simulates preliminary network designs for grid and off-grid systems, among other functionalities. In particular, as it relates to these aforementioned discussions about WTP and reliability, REM can enable an interesting choice experiment. Given that the model has the ability to stimulate various reliability levels and associated costs for each of connection types, such information could be used to create a set of hypothetical cost and reliability scenarios that are presented through a choice experiment or other contingent valuation methodology to consumers in a field-based trial. A set of potential experimental scenarios for consideration are offered as follows:

1. A probabilistic payment card method (highlighted in Table 3.2) can be used in conjunction with REM to present consumers with information on a set of hypothetical price increases that are associated with different forms of reliability and cost trade-offs, such as high impact low frequency outages (for example, a one-day outage) for grid-based electricity. Consumers can respond along a scale of 1-5, for example, to represent the level of certainty with which they would pay for a specified price increase in order to avoid the outage scenarios.

2. A multi bounded polychotomous choice experiment (highlighted in Table 3.2) can be applied using REM to present consumers with explicit sets of choices, such as 5 hours of reliable electricity in

the evening at X Rs/Month using the grid, 10 hours of reliable electricity in the afternoon and evening at X Rs/Month using a grid connection with a SHS, and innumerous other specific combinations of scenarios, depending on the numbers that REM can simulate. Given these sets of choices and ensuing specification of consumers' preferences, a curve that estimates WTP for different reliability levels can be generated.

3. Using the choice experiment method (highlighted in Table 3.2) – in which the respondent is asked to choose between pairs of programs, each with different attributes and costs – in conjunction with REM, a field experiment can be implemented that presents households with preset packages of service options, for a combination of grid and off-grid connections, as well as potential pathways and options for moving upward along the package of options toward higher reliability as ATP increases over time. To some extent, certain microgrid companies in India, such as Husk Power and Tara Urja, do offer these mixed options to micro-grid consumers and, as previously mentioned in the opening quote of this sub-section, a utility in Mumbai offers a reliability surcharge. Choice experiments can be set up using REM to formalize these "sub-products depending on the reliability and quality standards desired" (Rajagopalan [2015]), as well as pricing considerations.

4. An ultimate potential research experiment that can be enhanced through the use of REM involves applying the contingent behavior method (highlighted in Table 3.2). As a reminder, this method entails asking a respondent what he/she would do under specified hypothetical circumstances. Within this method, REM can be used to simulate and present information to the respondent about different costs and reliability options at different times of the day, including scenarios in which outages are communicated and not communicated in advance, and then the researcher can ask what the respondent would do in the hours in which electricity is unavailable to them, depending on the different cost-reliability scenarios that are randomized to the experiment participants. The outcomes of this experiment could arguably portray highly interesting and useful information about a more representative dynamic and nuanced cost of non-served energy, thereby improving the estimates that REM utilizes for CNSE in the model, beyond the substitute cost of kerosene.

While these aforesaid research ideas are, at this stage, very half-baked and high level, they serve the purpose of conveying several thought experiments that future researchers working on this area can consider and expand upon in order to further grow the nascent empirical literature on the relationship between WTP, reliability, and consumer attitudes and decision-making in both grid and off-grid settings. Outcomes from such forms of experiments and field trials arguably hold a great deal of value and importance to both business practitioners and policymakers working in the area of access, helping to give greater structure to the trial and error methods by which many existing off-grid companies operate, which continuing to not break even or achieve financial sustainability. Additional research and policy recommendations will be discussed in greater detail in Chapter 4 of this thesis.

3.7 Ability-to-Pay and Productive Uses of Electricity

…Countless electrification programs have suffered from a demand response of the commercial sector that lagged behind plans and expectations. With two significant consequences: First, the hoped for local development impacts of electrification did not materialize. Second, the electrification schemes suffer from a lack of new customers being able to pay for their electricity connection. Such developments have undermined the entire economic viability, and thus sustainability, of many electrification programs in developing countries
(Brüderle et al. [2011]).

While rural and household electrification initiatives in LIDCs have resulted in a wide array of positive outcomes for social and economic development, from increasing female employment and empowerment in South Africa (Dinkelman [2011]) and school enrollment and educational attainment in Brazil, El Salvador (Lipscomb et al. [2013]), and India (Khandker et al. [2012b]) to improving agricultural incomes in the Philippines (Chakravorty et al. [2016]) and health outcomes in El Salvador (Barron and Torero [2015]), there is also a growing literature that has unveiled less promising results from a macroeconomic perspective. For example, Burlig and Preonas [2016] find in a study on rural India that while electrified villages in India are consuming power, their energy use has not translated into significant changes in rural economies, with rejections of effects larger than 0.26 standard deviations across multiple indicators of economic development. Similarly, in an experimental study implemented in Kenya, Lee et al. [2016b] discuss that while demand for electricity indicates sizable economics of scale, consumer surplus is considerably lower than the total cost at all price levels, with projected welfare losses of $43,292 per community involved in a mass electrification program. While these aforementioned studies are not necessarily representative and may have some important methodological flaws, there is nonetheless a broad consensus that has emerged through ground-level experience and in the literature that simply extending grid or off-grid access and hoping for local economic activity to follow suit on its own is generally an illusion guided by false assumptions that access on its own is a sufficient precondition for stimulating growth. This is relatively unsurprising in the context of LIDCs, where there is often widespread multi-system failure – from high levels of unemployment, skill development, and lack of access to health, water, education, and transport to concerns about food security and crime – which bring forth a great deal of complexity into questions around the true benefits and costs of electricity access for development, as expressed in the opening words of this section from (Brüderle et al. [2011]). While some of these complexities have been discussed and are captured in the many aforementioned socioeconomic, demographic, behavioral, and technical parameters that sway consumers' beliefs and WTP for reliable electricity as compared to other public services that they also need, another core element that cannot be overlooked is consumers' ability to pay (ATP) and how much access can stimulate their long-term affordability through income-generating, productive uses of electricity. The remainder of this section will delve into the ways in which short-term and long-term liquidity and credit constraints are currently addressed and taken into consideration among governments and practitioners working the space of electricity access, including some of the advantages and disadvantages of existing strategies. I will further conclude with a brief discussion around areas of future research that are pertinent to this puzzle around ATP, productive uses, and economic development resulting from reliable electricity access.

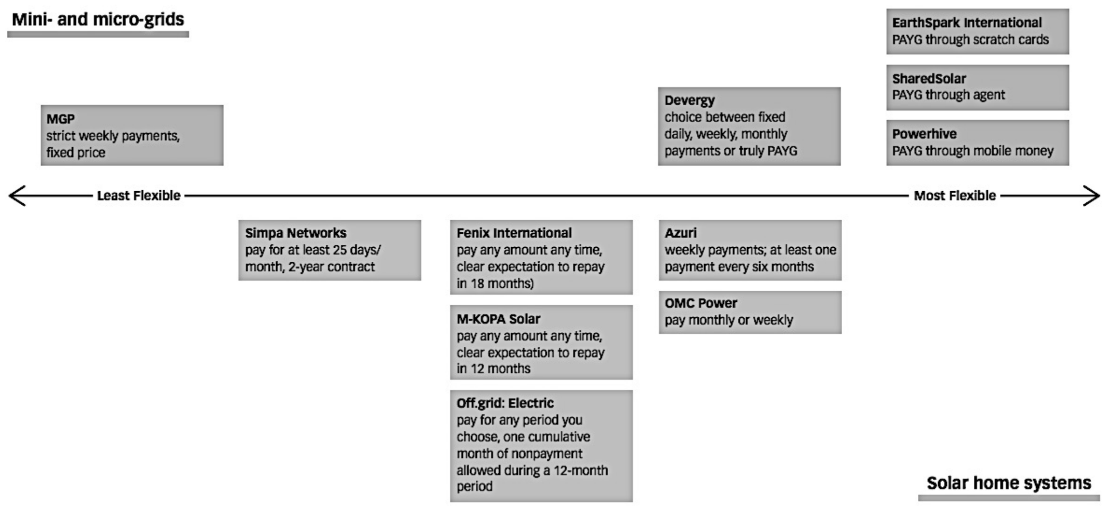
3.7.1 Existing Strategies for Addressing Ability-to-Pay

While ATP is less well understood and researched to date, a considerable number of strategies have been developed over the years to ameliorate challenges related to consumers' low and irregular income constraints, particularly in the off-grid business sector. Largely, many of the business models that have arisen in this space have been facilitated by the widespread prevalence of mobile banking systems, especially in sub-Saharan Africa, as well as improvements in smart metering technologies. In particular, the two most actively used flexible payment models that have been adopted by companies include pay-as-you-go (PAYG) models for off-grid electricity services, as well as the use of pre-paid metering to prevent electricity theft or meter tampering for grid-based electricity:

PAYG Models for Off-Grid Electricity Services

While PAYG services are less flexible than those offered in mobile telephony due to higher per-user costs, there is nonetheless general consensus among both mini and microgrid providers, as well as producers of solar home systems, that such broken down payment models have played a high significant role in scaling up services to consumers with ATP constraints. Different companies interpret and apply this model in various ways (see Figure 3.7) according to their own constraints, including differentiation in flexibility the timing, size, and means of payments, as well as the amount of energy that a consumer can purchase at any given time. In a set of surveys that were conducted by researchers from the ESMAP initiative of the World Bank in partnership with 11 off-grid providers, Moreno and Bareisaite [2015] found that the degree of payment flexibility is reflective of the circumstances and individual business models of the energy providers, as well as the trade-offs associated with each. Within this PAYG space, the four most prevalent sub-models include an asset-ownership model (rent-to-own), an energy-as-a-service model, a time-based pricing model, and a usage-based pricing model, and each of these models include a set of important advantages and disadvantages to consider (see Table 3.6). For example, most lease-to-own providers of SHSs are able to offer a decent level of flexibility with the timing of payments under the

Figure 3.6: Payment Flexibility Among Off-Grid Companies



Source: Moreno and Bareisaite [2015]

condition that these payments are made within a fixed period of time. In contrast, micro and mini-grid companies are likely to face more variable constraints. In India, for example, OMC Power is able to offer greater flexibility to consumers in large part due to a power purchase agreement with an anchor load customer that guarantees a steady revenue stream, whereas Mera Gao Power has less flexibility because, at the time of the survey, it did not employ smart metering technologies.

In spite of the overall initial success of these PAYG business models and their unique approach to helping extend access to the lowest income customer base, it is still too soon to judge if such mechanisms truly enable a sustainable business model and ability to scale-up to a greater number of users in the absence of increased payment flexibility. Nonetheless, some companies are trying to address such uncertainties, specifically around customer payment reliability, by engaging in educational marketing, pre-screening of customers, customer monitoring, and down payments for SHSs (Moreno and Bareisaite [2015]). In particular, the educational marketing tactics try to address a number of the behavioral biases that were previously discussed, such as mental accounting and inattention bias, by teaching customers of the benefits of modern energy services and cost savings associated with switching from candles or kerosene to off-grid systems. If the positive trends continue into the future, the customer and payment monitoring associated with these systems, including the consumer behavior data that arises from usage patterns, can help to facilitate the growth of access to other financial services. For example, in a useful paper on emerging digital finance business models and energy access for the poor, Winiecki et al [2014] discuss a number of important and interesting insights on the future applications of PAYG solar for improving financial services and the bankability of the energy poor:

> …Energy payment data from PAYG solar customers are already being used by these companies to inform future solar financing transactions, and could be used to extend other financial services to energy poor consumers who have limited access to formal finance. For example, another asset such as a television or water pump can be bundled with the PAYG product and entire product package value paid off through digital payments, with the energy services disabled if/when the customer misses a payment…[and] a customer can store excess cash in their prepaid solar account as a form of digital savings…[Moreover] data from PAYG products can give investors and donors financing the assets significant insights into performance and usage, improving efficiency for rural electrification financing. This data could be used by governments and regulators to better direct energy subsidies to target populations. In countries where significant government budgets are spent on fuel-based subsidies, new programs could offer digital transfers direct to consumers to be used on energy services of their choosing.

These emerging and rapidly adapting business models offer, as mentioned in the passage above, a number of exciting opportunities for future research and experimentation on targeted offers for the energy poor and arrangements that merge ATP considerations with other factors that influence their WTP and preferences around electricity services, such as appliance ownership and aspirations. These topics will be revisited in a bit more depth through case studies in Chapter 4 and recommendations in Chapter 5.

Pre-Paid Metering for Grid-Based Electricity

Another strategy that is currently implemented in some countries to address ATP challenges, in concurrence with issues around electricity theft and non-payment, is the use of prepaid electricity for grid-based services from utilities. This system of prepaid metering includes three main components, namely an electricity dispenser, a vending station, and a system master station (Ghosh, 2002)

Table 3.6: Advantages and Disadvantages of PAYG Models

PAYG Model	Description	Advantages	Disadvantages
Asset Ownership	Initial down payment and thereafter pay off remaining balance through prepaid usage until ownership (12-36 months)	Easy conversion of kerosene expenditures into micro-payments for clean energy; ownership of an asset appealing to consumers	Greater risk for the PAYG solar companies and difficulties determining competitive prices and viable repayment periods Difficult for consumers who do not want to commit to long-term financing relationship; social stigma around financial status of consumers using rent-to-own systems

Energy-as-a-Service	Consumers pay ongoing usage fee to company for prepaid days or weeks of usage without the ultimate option of ownership	Better risk management for both consumers and PAYG company Model potentially addresses consumer fear of technology obsolescence	Potentially more expensive than a rent-to-own model Potential issues around damage of equipment (adverse selection), resulting in higher after-sales service and maintenance requirements
Time-Based Pricing	Prepay usage in increments of time (days, weeks, month) and ability to use as much or little in that given time period within limitations of the battery capacity of the product	Model simplifies requirements and reduces cost for the embedded payment technology	Intensive pricing calculations required and holds the potential to be more costly to some consumers if they do not use for the entire payment period
Usage-Based Pricing	Main model used in national electrical grid billing systems where consumers are charged in pre- or post-paid kWh units	Attractive for consumers because closely matches variability in income and expenditures Potentially higher trust in the company because consumers are charged for what it actually used	Costlier for company because of payment hardware Can be more difficult for consumers to understand and manage usage in energy units if there is a lack of previous exposure

Source: Winiecki et al [2014]

and offers a wide array of advantages to utilities, such as better customer service, elimination of theft and bad debt, fraud control, and complete revenue management (Bandyopadhyay [2008]). Moreover, the prepaid systems present a variety of benefits to consumers as well, including easing bill payment, budgeting, and greater monitoring of and control over consumption (Bandyopadhyay [2008]; Makanjuloa et al [2015]). For example, in an extensive impact evaluative study conducted in Cape Town, South Africa in 2014, Jack and Smith [2015] found that the random introduction of prepaid meters resulted in a 13 percent decrease in electricity usage over the two-year period, which suggested that the change enabled customers to better understand and control their usage and budgeting. Furthermore, the study found that switching to prepaid electricity allowed for higher cost savings for poorer consumers and consumers with a delinquent payment history and also brought net benefits for the distribution companies as a result of higher reliability of payments. These findings are well aligned with a set of customer satisfaction surveys conducted in South Africa that found that "99% of customers were satisfied with the pre-paid program; 98% of the customers wanted to stay on the program, and 55% believe that they were changing the electricity usage patterns because of prepaying for electricity…[moreover] 84% of customers were satisfied with the change from the conventional billing to prepay; [and] 94% of the customers believe that the pre-paid system makes them more aware of the electricity use" (Bandyopadhyay [2008]). Such mutually reinforcing benefits can further spillover into improving a number of the cognitive biases highlighted earlier in the essay, including trust, reciprocity, and inattention biases.

As a result of these widely positive perceived benefits, pre-payment metering installations have grown around the world, with 4 million installations in South Africa, 40,000 in Tanzania, and 20-30,000 in South America. A notable exception to this trend, however, is India, where in 2008, only a few thousand prepaid metering systems had been installed, particularly in the State of West Bengal, resulting in a 15 percent increase in income for the West Bengal Renewable Energy Development Agency. Since 2008, the installation of prepaid meters has risen in New Delhi and a core mandate for the operational performance of the UDAY scheme is the mandatory deployment of prepaid meters for small consumers and smart meters for large consumers with every new connection in each state (Arora [2017]). In spite of this rapid push for widespread digitization of bill payment in India and extension of prepaid meters under the Saubhagya scheme,[44] a number of core barriers persist, including regulatory hurdles (Jai [2018]) and low consumer acceptance of prepaying for electricity (Bandyopadhyay [2008]). In particular, with regards to regulatory hurdles, there are currently no provisions in the Electricity Act for prepaid meters and the mode of electricity billing requires adaption with the mass rollout of the prepaid metering systems. If such systems work as well in India as they have in sub-Saharan Africa, they could play an important role in addressing ATP for grid-based Indian electricity consumers, helping to improve reliability in the long-run and moreover plausibly reverse some of the aforementioned negative behavioral trends related to poor reliability and WTP.

3.7.2 Productive Uses of Electricity

Beyond WTP and ATP for grid and off-grid electricity services, another core component of the long-term social and financial viability of electrification initiatives for the urban and rural poor includes the stimulation of productive and income-generating livelihood activities that depend on reliable energy access. While there is an active literature that documents short-term benefits of electrification for a number of economic development outcomes, including income, there is also a consensus that a so-called "Energy Plus" approach involving integration of non-energy inputs and greater resources for usage beyond just basic needs is necessary for breaking cycles of poverty in LIDCs (Palit et al [2015]). In this brief section, I draw from existing literature, first-hand interviews conducted in India, and case studies to answer the question: what conditions are necessary for enabling effective productive uses of electricity and what strategies are currently implemented on the ground? I further outline suggestions for future research on this topic.

[44] As mentioned in Chapter 2, this scheme aims to provide electricity connections to families in rural and urban areas of India by December 2018.

While the Government of India has carried out innumerous initiatives and reforms related to advancing access and electrification of households and villages, as enumerated in the previous essay, such top down programs and approaches have often failed to adequately integrate and link with rural development agendas and local resources to address access in a comprehensive way (Palit et al [2015]). As such, the Ministry of Rural Development launched a program called the National Rural Livelihoods Mission (NRLM) in 2011, which is focused on promoting institutions such as Self-Help Groups (SHGs) and cooperatives to facilitate effective last mile livelihood augmentation and self-employment opportunities. A subsidiary of this mission is the Society for the Elimination of Rural Poverty which bolsters the capacities of community-based organizations and offers livelihood- and geographically-specific services. While these initiatives have been found to result in positive electricity access related outcomes in livelihood clusters within the state of Andhra Pradesh,[45] Palit et al [2015] found less success in Madhya Pradesh, largely due to differences in the presence of effective institutions and their impact in advancing access to start-up finance, market access, supply of raw materials, and training:

> …the findings from the study in Andhra Pradesh shows that enabling government policy in the creation of community-based organizations can be considered to be the initial input, institutions or community based organizations such as the SHG network and the federation of SHGs the secondary input, and access to finance the tertiary non-energy input. The order of non-energy inputs is based on the order of non-energy input injection in Andhra Pradesh; this involved the…establishment of the SHG network, access to finance…followed by livelihood-specific inputs such as training, market access and access to good quality raw materials.

The effectiveness of such initiatives is even more questionable in off-grid contexts, where private operators can work largely outside of regulatory purview. For example, within the same study, the authors found that electrified households in grid-connected areas experienced greater changes in income as compared to households connected in off-grid areas, suggesting a more enabling environment for income-generating activities in grid-based settings. Consequently, many off-grid SHS and microgrid companies have been left to develop their own strategies through trial and error tactics within the communities in which they operate in order to better ensure their prospects for future growth (please refer to Box 3.5 for a case study example). As such existing strategies in both grid and off-grid contexts suggest several main conditions that are necessary for the successful development of productive use initiatives and programs: (1) improved packaging of electrification and employment schemes in both rural and peri-urban areas in order to advance joint and mutually-reinforcing missions; (2) creation of stronger ties with local banking institutions and agencies in order to make better use of local resources and networks, resulting in higher community-level trust and uptake; and (3) the establishment of more effective communication channels,

[45] In Andhra Pradesh, effective implementation of productive uses of electricity and access to non-energy inputs enabled benefits across multiple outcome variables: (1) households with access to electricity and non-energy inputs have higher income and consumption; (2) appliances are seen as potential livelihood-generating assets by households with higher non-energy inputs; and (3) access to non-energy inputs is associated with higher risk-taking in the form of entrepreneurship among households (Palit et al [2015).

potentially through mobile platforms, to provide widespread training and market access information to nascent entrepreneurs.

Given the relative recent recognition among policymakers, practitioners, and researchers on the importance of productive uses in the discourse around universal access to reliable electricity, there is still much work ahead to evaluate and study the best means by which to bolster these initiatives. For example, future researchers could consider the impact of other forms of safety-nets (i.e. pensions, insurance, scholarships, etc.) on accelerating rural and peri-urban households and businesses' to productively use electricity over a long-term time horizon (Palit et al [2015]). Moreover, economists and public policy researchers who are interested in studying institutions, governance, and trust could consider questions such as the following: does the effective implementation of productive use initiatives improve consumer trust and satisfaction with the service provider, as measured through outcome variables such as payment behavior? What potential positive or negative spillovers, if any, exist between disaggregated electrification programs and welfare or employment opportunity schemes in rural and peri-urban environments? In what ways can technology be leveraged for improving institutional coordination mechanisms between agencies that focus on electricity provision and other agencies that focus on advancing employment, health, and other public services? Answers to these question in the future will further clarify the best means by which joint policies and productive use programs can strengthen consumer ATP and WTP for electricity services in the long-run, and moreover which strategies will help to achieve multiple development goals simultaneously and in a cost-effective manner that maximizes positive spillover between programs. These insights are ultimately of great value to governments that must balance their budgets and funding dedicated to addressing a hodge-podge of development challenges within their jurisdictions.

3.8 Conclusions

There is a great deal of nuance, complexity, and uncertainty that underpins consumer WTP and ATP for reliable grid and off-grid electricity services in low income and developing countries, oftentimes involving a large number of socioeconomic, behavioral, and technical parameters that simultaneously and endogenously interact with and influence one another. An enormous amount of future work and research – such as the proposals presented earlier in this essay – is necessary to better separate some of the causal mechanisms behind the feedback loops between institutions and consumers outlined throughout this chapter. Nonetheless, the existing state-of-knowledge on these intersecting topic areas already indicate several important insights that I would like to leave the reader with:

1. WTP only exists below a certain level of affordability or ATP; or, in other words, WTP is, in large part a factor of income inelasticity over short and medium-term time periods;

2. In the range in which WTP does exist, it is dependent on a confluence of technical, socioeconomic, demographic, and behavioral characteristics that affect the ways in which consumers value different sets of grid, off-grid, and substitute electricity sources, as well as their subsequent attitudes and decision-making:

    a. From a socioeconomic and demographic angle, factors such as higher income, educational status, number of children of a school-going age, and ownership or aspirations for home businesses tend to be associated with an increase in WTP; in contrast, age, occupation, caste, and household structures have more ambiguous effects in the existing literature;

    b. From a technical angle, there is variability in WTP for electricity reliability (rather than baseline *access* to electricity) based on the ways in which reliability is measured or presented to consumers – for example, households' WTP differs based on frequency vs. duration of outages and whether the expectation of an outage is communicated beforehand. Such measurements and considerations are even further complicated when considering the full range of scenarios of poor reliability in LIDCs (ex. off-grid, under grid, idle grid, bad grid, good grid) and differences in households' ability and financial means of coping through dependence on alternative back-up sources or a cocktail of both grid and off-grid connections.

    c. From a behavioral angle, different forms of cognitive biases – including negative reciprocity, trust, reference dependence, status quo bias, mental accounting, and information and inattention biases – can theoretically bias consumers' WTP upward or downward and, oftentimes, the direction of the effect can depend or vary based on the aforementioned demographic, socioeconomic, and technical parameters. For example, the age or educational status of a household member has important implications for the degree of reference dependence, status quo bias, and inattention bias held and the ways in which this affects subsequent WTP. Moreover, different reliability measurements and management tactics, as well as the ways in which information is communicated to consumers, can hypothetically have profound effects on trust and the propensity to hold a bias of negative and/or positive reciprocity toward the government or an electricity service provider.

Box 3.5

Husk Power: Productive Uses in Rural India

"What is most necessary for us is the initial surveying and customer engagement: one needs to understand each and every mini-grid individually – the customer mix, productive use patterns…"

Husk Power is a solar and biomass micro-grid company in India that started operations in 2007 and now has about 80-90 plants that are either breaking even or are profitable. In order to stimulate productive uses in their off-grid electricity systems and enable economic growth, Husk helps many customers to start their own businesses – such as selling incense sticks, printing services, or water filters – and creates linkages with banks to provide financing and start-up capital to local entrepreneurs. In simultaneity with providing training to stimulate growth, Husk accommodates existing constraints (i.e. customer ability-to-pay) by implementing a pay-as-you-go or pre-pay billing system and providing subsidized initial connections. Moreover, for customers who lack steady incomes and default often, Husk provides them the option to consume much less power at an equivalent level of quality/reliability, in essence providing differentiated pricing and hours-of-connection plans. This mix of strategies has seemed to have pivoted the company and villages in the direction of a growth phase, with more and more consumers aspiring for more appliances.

Source: In-Person Interviews, July 2017

Box 3.6

Tata Power DDL: Productive Uses in Peri-Urban Slums in Delhi

Tata Power DDL, a joint venture (public-private partnership) between Tata Power Co. Ltd. And the Government of Delhi, currently services about 6 million people in the North and Northwest regions of Delhi. A large portion of these customers are based in large-scale peri-urban slums on the outskirts of Delhi, where there has historically been widespread incidence of theft and other socially-influenced forms of non-technical losses. In order to help overcome various challenges related to ability-to-pay and productive uses of electricity access, TPDDL created a *Social Innovation Group* within the company, which is dedicated to working with local NGOs to identify the social needs of the areas served and design effect interventions under a scheme called SSATHI, meaning "partner" in Hindi, to build acceptance, trust, and positive economic growth through the 233+ slum clusters. These efforts have ultimately culminated into over 350 women's literacy centers, 18 vocational training centers, 300 self-help groups, youth empowerment groups, and energy clubs in schools focused on teaching demand-side management strategies to younger generations.

Source: (Sinha [2017])

3. Given that WTP is partially a function of disposable income, it can, to some marginal extent, be enhanced and shifted upward through schemes that improve ATP in both short run and long run time horizons in grid and off-grid locations. In the off-grid space, short-term ATP is enhanced through the implementation of a variety of PAYG business models for SHSs and micro-grids, including lease-to-own services for basic lighting and charging services, which accommodate unpredictability and variability in the income patterns of the energy poor. In the grid space, short-term ATP has the capacity to be improved through the usage of prepaid smart metering systems, which benefits the financial health of distribution companies by improving payment behavior of consumers and reducing theft and benefits consumers by increasing the salience of their spending and enabling improved budgeting around their energy use. In the absence of corruption or other political and governance-related factors, such

strategies are further able to improve the reliability of electricity services, particularly for the grid, which can further address certain behavioral biases, such as negative reciprocity and trust, helping to reverse negative feedback loops and improve WTP.

    a. These PAYG and prepayment mechanisms have the potential to grow in their applications, as more data is collected on consumer behavior, credit history, and preferences. Such applications can include the extension of PAYG to additional, higher-wattage appliances or so-called social status goods, which further strengthens consumers' WTP and valuation of electricity services as they gradually move along the ladder of opportunities provided by reliable grid and off-grid supply sources.

4. In the long run, particularly in remote rural areas, ATP and WTP are further advanced by the provision of resources that stimulate productive, income-generating activities. In contrast, infrastructural and other systematic development challenges negatively affect WTP and ATP, even in areas in which it may exist and be high. As such it is necessary for government ministries and agencies to better coordinate strategies and not operate in isolation of one another, in order to stimulate village and peri-urban economies in a comprehensive and sustainable manner.

5. The appetite and interest in research projects and evaluations on these aforementioned topics is ripe and active, including on behavior and energy access, as well as the impacts of reliability on WTP and welfare effects of electrification initiatives. Attention should be paid to the conclusions that come out of these studies in the coming months and years, as they will serve to better separate causal effects and subsequently inform the most targeted steps that companies and governments can take to intervene against particular determinants that negatively affect consumer WTP, thereby reversing existing negative trends. Moreover, additional research, such as contingent valuation choice experiments, on the interactions between ATP, WTP, and reliability will further help to augment the capacities of top-down technoeconomic optimization models, such as REM, by also bringing increasingly realistic bottom-up perspectives and inputs about consumer behavior and demand into grid and off-grid network planning.

In the next and final essay of this thesis, I aim to incorporate these insights into a set of concrete policy recommendations and behavioral design strategies that can be embedded into both existing and new business models for grid and off-grid electrification planning in LIDCs.

Chapter 4

Toward a Comprehensive Approach to Grid and Off-Grid Business Model Planning

Universal and reliable electricity access planning in low income and developing countries is reaching a profound turning point, with an increasing number of stakeholders – both within the government and private sector – starting to recognize the need for a shift and thinking out of the box, especially with regards to addressing entrenched challenges in the distribution sector. As emphasized throughout this thesis, a central figure in this shift is the low-income rural, peri-urban, and urban consumer of both grid and off-grid electricity services, with researchers and practitioners increasingly documenting the widespread and complex variability in the needs and aspirations of the energy poor; economic, political, and technological constraints they face; sources of differentiation in their psyche and valuation of various attributes of electricity services; and the opportunities for future productive growth that are available to them. Given the breadth and depth of nuance embedded in the attitudes, behavior, and decision-making processes of the energy poor, combined with the oft uninviting, uncertain, information poor, and difficult sociopolitical and economic environment in which they operate, there is a need among entities involved in electrification initiatives to take a step back and look at the challenges with an enhanced, wide angle lens. In particular, the time is ripe for greater integration of human or user-centered design[46] principles and human factors[47] thinking into new policy and business model designs for universal access to energy.

In this essay, I bring together and combine a number of the insights from the previous essays into a set of concrete recommendations, based on the current state of knowledge, and further conclude with recommendations for future work and research. As was discussed in the introduction of this thesis, the previous essays were largely organized around the overarching research questions of (1) *how did*

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[46] Human-centered design, also called user-centered design or user-driven development, is a process that avoids making assumptions, works closely with end-users to understand their needs, and involves repeated testing and iteration of design solutions.

[47] Human factors psychology is a discipline that examines human behavior and capabilities in order to determine the most impactful ways in which to design products and systems that maximize safe, effective, and satisfying use by consumers.

we get here and what does 'here' entail? And (2) *what are some of the current puzzles and challenges involving consumers, and how do these factors impact their decision-making, attitudes, and perspectives*? Now, this final essay arrives at the question of *where can we go in the future, knowing what we know now? What questions should future research prioritize in order to tackle these systemic challenges in the distribution sector of many low income and developing countries?* The remainder of this essay is motivated by this latter set of questions and is organized as follows: in Section 4.1, I introduce the concept of 'nudge' behavioral design or choice architecture (Sunstein and Thaler [2008]) and discuss ways in which these strategies have been and can continue to be integrated into access planning, through both technology-facilitated tactics as well as ground-level capacity building. Next, in Section 4.2, I elaborate upon a number of approaches utilized within existing business models to try and improve direct engagements with and incorporation of electricity consumers' needs, such as distribution franchises in India and rural cooperatives models around the world, and further lay out a brief conceptual framework for a new business model for electricity distribution in India, called the Energy Company of the Future or ECoF. Lastly, in Section 4.3, I highlight areas for future research and questioning and Section 4.4 concludes the thesis.

4.1 Nudge Theory and Behavioral Design

A big question that people are shifting to thinking about is: how do we transform the mindset of the consumer?

-Dr. Debajit Palit (Palit [2017])

In the last decade or so, policymakers and academics working in the area of behavioral economics have increasingly focused on so-called behavioral failures that result from irrational decision-making and ultimately may preempt individuals from maximizing their own welfare in the long-run (Pollitt and Shaorshadze [2011]). In a seminal body of work that ultimately paved the way for the 2017 Nobel Prize in economics for Richard Thaler, Sunstein and Thaler [2008] argue for the implementation of a "choice architecture" framework of "libertarian paternalism," (Sunstein and Thaler [2003]) in which individuals are "nudged" toward welfare-maximizing outcomes through a combination of strategies that derive from studies in behavioral economics and cognitive science, such as the proper framing of choices and provision of appropriate default options. Oftentimes these strategies can build off of or root from a number of the behavioral biases that were highlighted in earlier essays, –particularly on behavioral influencers of WTP – such as negative reciprocity, trust, reference dependence, loss aversion, mental accounting, consumer myopia (short-sighted decision-making) and attention and information bias. A more wide-ranging set of references and explanations on key behavioral phenomena that influence "nudge" theory and design can be found in Table 4.1 below.

Table 4.1: Behavioral and Cognitive Phenomena Used in Nudge Design

Behavioral Factor	Description	Example(s)	Nudges	Source
Time-varying preferences and hyperbolic discounting	Individuals tend to have higher discount rates in short time horizons and lower ones for longer time horizons, which can imply short-sightedness in analyzing costs of benefits of immediate decisions versus decisions in the future.	Goals or decisions that individuals tend to procrastinate on or have self control challenges with, such as weight loss goals, quitting smoking, or saving money toward retirement, are concrete manifestations of this behavioral paradigm.	Commitment devices, such as a bank account that restricts when funds can be withdrawn, are constructed to control impulsive behavior and limit choices toward achieving long-term goals	Laibson [1997] Wilkinson [2007] Ashraf et al [2006]
Loss Aversion	The tendency for individuals to value losses more deeply than gains	Contingent valuation studies tend to consistently find a higher willingness-to-accept (WTA) than WTP	Used in *framing* how information is communicated	Kahneman and Tversky [1979] Shogren and Taylor [2008]
Status Quo Bias	The tendency for individuals to prefer the current state of affairs	Individuals tend to stick to default options that are chosen for them, instead of making modifications	Implementation of opt-in vs. opt-out approaches; automatic transfers; reduction of hassle in take-up of service	Pollitt and Shaorshadze [2011]
Bounded Rationality	Bounded rationality involves constraints on optimal cognitive processing, such as decision-making burdens arising from choice or information overload, which can subsequently lead to erroneous mental shortcuts and heuristic decisions.	Individuals are, for example, more likely to purchase a grocery item when offered with six choices, as compared to being presented 24 choices.	Simplification of information presentation; increasing salience of information	Iyngar and Lepper [2000]

Prosocial Behavior, Altruism, Social Signaling and "Warm Glow"	Prosocial behavior relates to individuals' attitudes toward contributing to public goods and the "warm glow" effect refers to the propensity for individuals to contribute to a social good because it makes them feel good – either about themselves or for the ways their action influences what others think of them. This often relates closely to social norms, signaling and status/image effects that try to shape public opinion toward an individual.	Use of personalized emails and texts, rather than generic messages, increased likelihood of donation to charity. Incorporating language that "most people do" a specific action (such as pay taxes on time) can increase response and individuals' likelihood to follow what "most people do."	Social recognition and/or social shaming tactics; information framing	Pollitt and Shaorshadze [2011] Algate et al [2014]

4.1.1 Nudge Applications in Middle, High, and Low Income Countries

Nudge strategy and choice architecture, oftentimes designed by government nudge units such as the UK Behavioral Insights Team, are often highly low-cost interventions and have been applied creatively and effectively to a wide range of policy areas, including applications related to the energy sector, increasing consumer payment behavior (particularly for taxes), and, to a smaller extent, to challenges within the context of LIDCs. Prior to enumerating a series of ideas for ways in which to specifically integrate behavioral design into grid and off-grid electrification planning in LIDCs, I will first provide a brief review of existing literature and findings on nudges that have been implemented and experimented with in different policy and business spheres.

Choice architecture strategy and design has been applied relatively extensively in the energy sector of middle and high-income countries, with a particular focus on ways in which to influence pro-environment or "green" behavior and energy consumption. For example, Herberich et al [2012] carried out an experiment with door-to-door salespeople to assess the ways in which both altruism and social pressure mechanisms influence consumers' pro-social behavior and motivation to purchase energy efficient light-bulbs, finding a monetary value of about \$1.40 - \$3.50 out of \$5.00 in the purchase price for CFLs being attributed to social norms, rather than price. Similarly, among the most widely cited examples of a nudge is the application of Home Energy Reports (HERs), which are single page letters that compare a household's energy consumption to that of their neighbors and essentially play on cognitive parameters such as social signaling (Allcott and Kessler [2015]). While this nudge strategy has mixed evidence on its effectiveness, from Allcott [2011] finding a mild 2 percent consumption reduction and Ayres et al [2013] finding a similar 1.2 – 2.1 percent reduction to Costa and Kahn [2010] finding an *increase* in consumption among political conservatives as a negative reactance to a normative nudge they may disagree with, it has nonetheless inspired innumerable other field trials involving the application of social comparison, social normative messaging, energy efficiency / cost-saving labeling, and informational nudges for energy conservation (Delmas et al [2013]; Newell and Siikamaki [2013]).[48] An additional nudge strategy that has been employed and experimented with in the context of green energy includes the use of default options or opt in/opt out, with Pichert and Katsikopoulos [2008] finding that, regardless of consumers' attitudes toward green energy, they will often stick with whatever the default option is, suggesting that this nudge may indirectly promote pro-environmental behavior by overcoming status quo bias among consumers. Moreover, yet another valuable tactic that has been particularly facilitated by computerized and interactive tools is the use of feedback and informational salience nudges. For example, Fischer [2008] finds that appliance-specific feedback provided frequently over a long period of time positively influences consumers' ability to control their energy consumption and save money. Such feedback systems will be increasingly important and interesting to study in the context of the rise of "smart" two-way communication platforms, such as those highlighted in Chapter 2 (Lee et al [unpublished]).

Another key policy area in which nudges have been actively applied is tax compliance. While tax compliance is not explicitly relevant to universal access, the challenges embedded within this policy issue are arguably highly analogous to issues around bill payment and electricity theft discussed in previous chapters, and thus merit discussion. Even though the majority of these nudge interventions have been tested and trialed within middle and high-income countries, they nonetheless may provide important insights on similar endeavors in LIDCs. The most common nudge tactic that has been applied to this policy area is social normative, threats, and moral suasion messaging, with the literature indicating mixed results: for example, Behavioral Insights Team [2012] found in a randomized controlled trial that treatment groups that received a message that "9 out of 10 people in your ____ pay their tax on time" had a 15 percent greater compliance rate as compared to the control group. Similarly, in a large-scale experiment conducted in Austria, Fellner et al [2011] found that if the treatment group received a letter with threat-framed language (i.e. "if you do not respond to this letter, we will contact you personally"), payment and compliance behavior improved, with this finding further supported in a U.K-based study by Hasseldine et al [2007]. In contrast, a number of studies have also found that social normative messaging (for example, "94 percent of people pay their taxes) or moral appeal messaging (for example, "paying your taxes is the right thing to do") had little to no effect on compliance (Blumenthal et al [2001]). Additional experiments in this policy space have involved the use of personalized and simplified information messaging, salient communication about benefits, and text-message reminders (Pollitt and Shaorshadze [2011]). While the majority of these

[48] The ways in which information is framed and presented can also result in varying effects. For example, if information is presented as "money saved" through the purchase of energy efficient appliances versus "money lost" by sticking to the status quo, there may be profoundly different impacts on consumer behavior as a result of the cognitive parameter of loss aversion highlighted in Table 4.1 (Kahneman and Tversky [1979]).

nudge experiments and studies have been carried out in middle and high income countries, a small but increasingly number of researchers are beginning to extend similar concepts and interventions to the specific context of different LIDCs, including applications related to energy and collective action problems such as payment compliance. A summary of this nascent literature can be found under Table 4.2.

Table 4.2: Energy, Payment Compliance, and other Collective Action Nudge Experiments in LIDCs

Policy Area	Country	Nudge	Results	Source
Tax Compliance	Bangladesh	The experiment applied two nudge tactics: (1) peer recognition and (2) recognition cards. Firms in treatment (1) were informed that their compliance behavior would subsequently be made public to neighbors in a letter and firms in treatment (2) were informed about their eligibility for gold, silver, and bronze recognition cards based upon their tax compliance and the compliance of others in their cluster.	Treatment (1) increased compliance, especially among firms that did not pay in previous years, whereas treatment (2) did not result in any significant changes in compliance behavior.	Chetty et al [2011]
Hygienic Latrines	Bangladesh	The experiment assesses the effects of social and financial nudges on affecting a local collective action problem related to investment in hygienic latrines and maintenance. The treatments include (1) a financial or a non-financial “social recognition reward” and (2) and whether households were encouraged to make private or public pledges.	Study ongoing, but outcomes hypothesized include: (1) public pledges will increase latrine ownership and access rates; and (2) incentives and rewards for group-level performance in achieving a given level of latrine ownership will increase access rates.	Bakhtiar et al [2017]
Payment Compliance	India	Tata Power DDL, as part of its Social Innovation Group, apply social pressure, shaming, and signaling nudges by color-coding and publically tagging meters with the colors in their slum cluster services areas in the north of New Delhi to indicate whether a household is paying their electricity bill or not.	This strategy, along with a number of other tactics, helped to improve payment behavior. No specific information on causal impact, as this nudge was explained anecdotally in an interview.	Sinha [2017]

Energy Consumption	India	This experiment, which was conducted in New Delhi, had two treatment groups: (1) the first group received weekly report cards providing feedback on the households' electricity consumption from the grid (low cost) and from backup diesel power (high cost), as well as comparisons to the consumption of others in the community and information on general savings tips; (2) in contrast, the second treatment group received the same weekly reports but were also enrolled in a monetary rewards scheme, where starting balances would increase if consumption was lower than peers and decrease if it was higher than peers.	The study had three major findings: (1) the weekly report card group (without the rewards scheme) reduced average household electricity usage by 7 percent, except during outages; (2) the information nudges also made households more responsive to tariffs; and (3) interestingly, when monetary incentives were added, households no longer reduced consumption, possibility because of "emerging distrust when offered a financial contract," particularly in an already low-trust environment.	Sudarshan [2017]
Energy Consumption	South Africa	While this study was not explicitly set up and framed as a nudge analysis, the researchers studied the introduction of pre-paid metering, which provided better informational salience to consumers on their electricity consumption.	The introduction of prepaid metering resulting in a 13 percent decrease in electricity usage over a two-year period, potentially as a result of consumers better understanding and controlling their usage and budgeting.	Jack and Smith [2015]

Source: Author Compilation [2018]

4.1.2 Limitations of Nudge

"The challenges identified raise important design questions for policymakers moving forward, not just in India but in other developing countries as well…[and] these tools [nudges] are a wonderful opportunity for policymakers, but there is an art to using them effectively." – Sudarshan [2015]

Although there is a highly active appetite for continued extension of the applications of choice architecture and nudge design to different public policy and collective action problems, with the United Nations even turning to nudges as a low-cost means of advancing progress in the SDGs (Economist [2017]), there are also a number of potential limitations that should be taken into consideration. In particular, due attention must be given to the nuances and idiosyncrasies of specific contexts when designing nudges: for example, the inclusion of monetary incentives in the Sudarshan [2017] study cited above in Table 4.2 ended up backfiring, likely due to a pre-existing lack of trust between consumers and the utilities or government. Moreover, Allcott and Kessler [2015] argue that while nudges are effective at significantly altering behavior, "they need to be evaluated based on their welfare implications," as some designs may end up disproportionately hurting particular users (Handel [2013]), including the poorest consumers. Ultimately, there is a need to proceed carefully with the design of these nudge policies to ensure that (1) it does not rebound as a result of overlooking underlying cultural or social phenomena of a specific context and (2) provides for a well distributed set of social welfare outcomes.

4.1.3 Recommendations on Behavioral Design for Universal Access in LIDCs

In this section, I draw from both the multifarious insights and context discussed in previous chapters, as well as the information on behavioral constraints, effective nudges, and their potential limitations highlighted in the preceding sections of this chapter, to begin to answer the overarching research question I posed in the beginning of the chapter: where can we go in the *future*, knowing what we know now about the different challenges in the distribution sectors of LIDCs? While one evident and major supply-side component of helping to address a variety of the problems highlighted throughout this thesis is to improve baseline reliability and quality of power in a way that is clear and apparent to consumers, there are numerous complementary measures that are also necessary to move toward sustainable, long-term shifts in the attitudes and behavior of consumers. In this section on nudge and behavioral design, I focus on the latter, while the subsequent section more explicitly focuses on the former, through a discussion of existing and new business models that move toward greater assurance of electricity supply quality. In this section, I approach answering and exploring this overarching future-oriented question through diagrammatic visual representations, in which I first highlight a specific consumer-based behavioral challenge, discuss the potential underlying causes, and thereafter present a number of context-tailored nudge and/or other incentive-based interventions that could be tested by public or private electricity service providers for both grid and off-grid systems. A brief discussion will ensue after each of the diagrams, respectively. Specifically, in Figure 4.1, I first examine the topic of electricity theft, tariff hikes, and bill payment, and thereafter briefly discuss specificities on the strategies presented. Thereafter, in Figure 4.2, I consider challenges related to consumer ATP and similarly discuss the nudge and incentive-mechanism strategies highlighted. Ultimately, in Figure 4.3, I examine the topic of consumers' appliance ownership and aspirations gaps and conclude with a discussion.

Nudge Strategies Related to Electricity Theft, Tariff Hikes, and Bill Payment

Figure 4.1: Electricity Theft, Attitudes Toward Tariff Hikes, and Bill Payment Strategy Design

Underlying Cause	Design Tactic	Implementation
Collective Action Problem: "Everyone steals"	Social Shaming or Social Recognition	• Physical tagging of meters. • Color coded electricity bill. • Positive recognition of *consumers of the week* in bill letters, social e-payment platforms, or house-to-house collection. • Feedback on payment relative to neighbors. • Public group or individual pledges to pay.
Lack of trust and negative reciprocity toward provider	Salient information framing, operational transparency, personalized messaging	• Made price notches salient in bills. • Employ local sales network with trusted (female) members of a community. • Provide a try-before-you-buy option for testing a service and building trust, with the potential experience of loss aversion when the trial period is over. • Simplified information on relationship between bill payment and electricity reliability. • Text messages before planned outage.
Misinformation or inattention bias about tariff or subsidy	Salient information framing, personalized messaging	• Simplified text messages on facts like "the government pays X% subsidies for energy." • Loss framed messages about average (high) expenditures on back-up diesel versus actual (low) payment for electricity bills. • Local and simple workshops on tariffs and "where the money goes."
Status quo bias, preference to pay for back-up technology	Loss aversion information framing	• Loss framed messages about average (high) expenditures on back-up diesel versus actual (low) payment for electricity bills. • Gain framed messages on money saved by paying for bill, rather than back-up generators.

Within the context of LIDCs, such as India, where baseline trust and reciprocity is low – with evidence on outbreaks of violence and hostility when utility employees go to enforce bill payment, – nudge strategies that utilize pecuniary "threat" framed messaging or social shaming effects, rather than nonpecuniary social (individual or group) recognition may end up backfiring. Moreover, there can be a great deal of receptivity or rejection of framed information nudges depending on *who* or what entity is communicating the information (Frederiks et al [2015]): a threat or shamed-based nudge may carry much more weight when the information is communicated within a community by a trusted local leader, rather than if it is communicated by a service provider who is perceived as illegitimate or untrustworthy in the public eye. As such, a degree of experimental testing, whether formal or informal, should be carried out by the public or private provider, in partnership with a regional community network, in order to best assess the social signaling design that would work most effectively and sustainably over a long timeframe while taking the particular social and cultural norms of a region into account.

Nudge Strategies Related to Improving Challenges Around ATP for Electricity

Figure 4.2: Low ATP for Electricity Connection and/or Bills

Underlying Cause		Design Tactic		Implementation
Poor savings habits, hyperbolic discounting; mental accounting	➡	Default savings options; personalized goal-setting; information framing	➡	• If in formal banking and employment sector, consumers can be enrolled in a default program that automatically transfers a % of income toward saving for energy bill payment. • If in informal banking and employment sector, work with local rotating savings and credit associations (ROSCA) to create a community savings pool dedicated to energy expenditures. • Broken down PAYG systems to alleviate issues around mental accounting. • Potential application of PAYG to connection fee. • Government conditional or unconditional cash transfers or ration cards for energy. • Consumers can set savings goals and receive active personalized feedback on progress. • Personalized messages framed as (monetary, health, time) "losses" from relying on kerosene, diesel generators, and other informal power.
Unstable employment, lack of income-generating activities	➡	Increase information salience, personalized messages	➡	• Personalized messaging to agricultural workers on market data and prices for produce to close information gaps. • Entrepreneurial goal-setting and personalized messaging on local training opportunities.

As discussed in the previous set of comments on Figure 4.1, sensitivity to local cultural and social norms is also necessary as it relates to consumer ability-to-pay. For example, Sudarshan [2017] found that a financial incentive scheme that involved monetary awards for energy conservation and deductions for poor conservation practices rebounded, likely due to low-income consumers' mistrust toward particular financial contracts. As such, there is a potentially high likelihood that default (opt-in/opt-out) schemes for saving money may have lower levels of acceptance, as compared to an individual or pooled savings mechanism through locally trusted savings and credit groups that partner with the electricity service provider. Moreover, the efficacy of a number of the personalized messaging tactics may be contingent on the prevalence of mobile application and mobile payment adoption within a particular country or region. For example, while rural market and commodity price data and information has been largely provided through phones in various African countries, such as Niger (Aker [2010]), it has rather been dispersed through the establishment of local Internet kiosks and warehouses in India (Goyal [2010]). Thus, a sensitivity to both technological and cultural constraints should be maintained when designing nudges and other forms of interventions related to enhancing ATP. In the final diagram that follows, I consider a set of interventions that public or private providers of grid-based and off-grid electricity services could test and implement to address constraints related to the gap between the appliances that consumers aspire for, versus the appliances that they currently own.

Nudge Strategies Related to Closing the Gap Between Appliance Ownership and Appliance

Figure 4.3: Gaps between Appliance Ownership and Aspirations

Underlying Cause		Design Tactic		Implementation
Poor ability-to-pay for desired appliances; liquidity constraints	➡	Default savings options; personalized goal-setting; commitment device; information framing	➡	• When signing up for a certain level of off-grid services, consumers could either opt-in or opt-out (default more effective) of an option for a pre-specified surcharge (i.e. commitment payment) on their energy bill that goes directly into a savings account for purchasing appliances when enough money becomes available. • If high-wattage appliances are aspired for (such as TVs or refrigerators), consumers can opt for a monthly surcharge on current energy bill that goes into a savings accounts that unlocks when enough is saved to graduate to a higher level of electricity services that handles higher wattage appliances. • When signing up for services, consumer can set goals and timelines for specific aspired-for appliances and the service provider can provide salient and simplified information about how long it would take to save for the specified appliance if the consumer saved X amount/month. • Extension of PAYG or lease-to-own for appliances.

Lack of trust in provider or appliance vendor; poor O&M	Salient information framing, operational transparency, personalized messaging	• Provide a try-before-you-buy option for testing a service and building trust, with the potential experience of loss aversion when trial expires. • Work with local aspiring entrepreneurs, i.e. individuals who are known and respected within a community, to be the familiar “face” and vendor of the product in a specific network. • Personalized messaging to consumers about where to obtain O&M services, establishing clear expectations about when and where services are available.
Status quo bias, consumers biased toward current ownership and usage habits	Loss framing, social signaling, personalized messaging	• Provide a try-before-you-buy option for testing a service and building trust, with the potential experience of loss aversion when trial expires. • Highlight consumers who have purchased new appliances within a specific community and have them share their stories with others in the neighborhood – either digitally through a mobile application or in-person. • Provide a “platinum” status to consumers who meet a goal to purchase a new appliance, which others in a neighborhood can publicly see. • Personalized messaging to consumers about benefits conferred from using a specific appliance, compared to whatever method is currently used in a household.

In the same spirit as the previous discussions, when planning for nudges and other forms of interventions to close gaps between consumers’ appliance ownership and aspirations, it is important for electricity service providers to approach their design with an understanding of local phenomena that may vary with local economic and social conditions. For example, while opt-in/opt-out nudges for saving for specific appliances may work relatively well in a context where the consumer relationship with a service provider is strong and well trusted, in another context it may be poised to fail in the absence of ground-level capacity and trust-building over a longer period of time. If this complementary trust-building does not occur in environments with high information asymmetries and poor communication about expectations, consumers will likely perceive the above-mentioned “appliance savings account” as a scam or means for the service provider to steal their money. As such, an initial analysis of attitudes toward government vs. private electricity service provision and randomized testing of different nudge tactics, such as some of the analyses conducted and discussed in the previous chapter, is important for creating a realistic understanding of the respective background of a specific country and context (Never [2014]).

4.2 Toward an Integrated Business Model for Universal Energy Access

As has been argued at length throughout this thesis, in order to advance in a sustainable and inclusive manner toward the goal of universal energy access by 2030 or beyond, the traditional business models, institutional coordination mechanisms, and planning policies need to adapt and readjust to more accurately reflect and appropriately react to the complex social-cultural-behavioral systems and historic perpetuators of negative feedback loops that plague the distribution sectors of innumerable LIDCs. While these feedback loops have persisted throughout periods of reform in India, as well as in numerous countries in sub-Saharan Africa, there has also been a recent surge in research on variables that underlie these feedback loops, in order to better understand the most effective pain points and ways in which to break and reverse its direction. In particular, much of this research has been centralized around (1) developing a subtler comprehension of the energy poor and the different parameters that affect their attitudes, behavior, and subsequent decision-making on short and long-term horizons in both grid- and off-grid settings and (2) complicating the ways in which core metrics – such as WTP, ATP, CNSE, utility, welfare, "energy poverty," reliability, and access – are measured and interpreted in different developing contexts. Although there is a great deal of research that remains to better separate causal effects and move from theory and anecdotal evidence to more quantitative, field-based experimental evidence from numerous countries and environments, the current state of knowledge nonetheless already provides important starting points for rethinking ways in which to develop more effective business models for extending access to all. Specifically, these new pro-poor business models, as well as their complementary regulatory mechanisms and strategies for local market development, require a more integrated approach that aims to leverage and combine advancements in technology, – such as the rise of smart meters and e-based citizen engagement and communication systems, – with innovative ground-level trust and capacity building, demand side management, and other forms of incentive mechanisms to better bridge various divides and information asymmetries that exist between service providers and consumers.

There are already examples of intelligent business models in the off-grid space that have successfully incorporated a number of the aforementioned factors into their electrification planning approach. For example, the widespread implementation of innovative financing solutions, such as the variety of PAYG systems (see Table 3.6) and prepaid electricity metering for off-grid solar home systems effectively identified and addressed affordability and ATP-related behavioral constraints such as poor mental accounting and hyperbolic discounting by breaking payments into smaller increments (Never [2014]). Similarly, numerous microgrid companies, such as Husk Power in India, applied community-tailored strategies through years of active trial and error to gain consumer trust, for example through home safety and use demonstrations by employees to increase the salience and accessibility of information about products to consumers, as well as personalized communication about training opportunities for aspiring entrepreneurs. Creatively framed social signaling, recognition, and shaming nudges and community trust-building solutions have also been applied by grid-based distribution companies, most notably Tata Power DDL in New Delhi (revisit Boxes 3.1-3) to overcome persistent challenges such as those described in Figure 4.1 on negative reciprocity and information biases. However, many of these off-grid and grid solutions have been developed in relative isolation from one another, resulting in a fragmented market and consumer base, such as those laid out earlier in Table 3.1. As such, there is much room for additional innovative thinking to better coalesce these scattered solutions and strategies together to provide more integrated electricity services to the various tiers of energy poor consumers. In the following section, I briefly present two existing business models that have aimed to surmount the array of challenges embedded in the distribution sector of different LIDCs: the urban and peri-urban distribution franchise model in India and rural cooperative model that has been applied in a number of countries around the world. Thereafter, I will present a conceptual model that aims to incorporate insights from the successes and failures of preceding models, strengthen the integration of human factors, and better amalgamate the existing dispersed solutions into a holistic approach to electricity distribution.

4.2.1 Case Study of an Existing Model: Distribution Franchise

In the most general terms, a distribution franchise (DF) is a public-private arrangement in which the DF operates as an intermediary between the distribution utility and end consumers within a licensed area of the distribution company for grid-based activities (Anand and Sambit [2009]). Under a DF, given that the state, in most cases, retains ownership of assets, this model falls completely short of privatization. Nonetheless, it instead leverages corporate best practices and advanced technologies to reduce aggregate technical and commercial (AT&C) and subsequent financial losses for state distribution companies, achieve predictable cash flows and consistent bill payment from customers, and enable a more attractive investment environment. Distribution franchises largely emerged in India after 2003 and have been adopted in different forms, including metering, billing, and collection-based (MBC) franchises, input-based distribution franchises (IBDF), input-based franchise-incremental revenue sharing (IBF-IRS) and input-plus-investment based franchises, with the latter considered to be the most prominent model (Gupta [2016]). Key characteristics of the various arrangements can be found in the following table, adapted from Gupta [2016], Anand and Sambit [2009], and P-Manifold Business Solutions [2012], and further supplemented by in-person interviews in July 2017 with Tata Power DDL, The Energy and Resources Institute, and the Shakti Foundation.

Table 4.3: Distribution Franchise Models in India

Franchise Model	Main Characteristics
MBC	An MBC franchise is essentially an outsourcing model meant to improve operational efficiency, with a fixed-fee compensation and bidding criteria – sometimes with and other times without incentives. This arrangement generally attracts smaller players. While this franchise allows for high political acceptance, it entails a slow reform process and can be vulnerable to confusing accountability mechanisms, as the DF bears the public face to consumers, while the physical quality of the service mostly depends on the owners of the assets.
IBDF	IBDFs are based on 10-15 year long-term contracts and a leasing model, wherein the discom leases its assets to the DF and the DF takes care of all O&M. In this model, the franchisee gets a fixed input price power purchase from the distribution company. The DF has the right on revenue, while the distribution company receives the input power purchase price and gets the depreciated value of the capital expenditure at the end of the long-term contract. Conditions that are key for the successful scaling of the IBDF model include clear and measurable standards of performance, as well as independent performance and customer service monitoring to ensure good governance structures. This model falls in the middle of the spectrum with regards to political acceptance and speed of reform.
IBF-IRS	IBF-IFS models are based on 5-7 year short-term contracts, in which the input energy is delivered to the DF without payment and the incremental revenue obtained beyond the baseline revenue-per-unit (RPU) is shared between the utility and franchisee based on a ratio that is pre-defined in the contract. If the base of the RPU of the DF is not realized, a penalty is imposed on the DF. Furthermore, under this arrangement, all assets below the distribution transformer are maintained by the IBF-IRS DF and the DF is also mandated to install smart meters, with a 40-month recovery period through monthly meter rent. This arrangement usually attracts smaller players.
Input-Plus-Investment	The Input-Plus-Investment based model is similar to the IBDF, with the exception of a longer-term (15-20 year) contract period. Under this model, the responsibility of the DF includes operation of supply from identified input points, MBC, O&M, and capital expenditures. With regards to compensation and bidding criteria, the DF has the right on revenue, the distribution company receives bulk supply charges and depreciated value of the capital expenditure. The benefits of this model include operational, technical, and collection efficiency, reduction in distribution losses, improvement in services, manpower reduction, and greater savings due to avoided investments.

There are currently five states in India that have operational distribution franchises, including Maharashtra, Bihar, Uttar Pradesh, Odisha, and Rajasthan, each of which have had mixed experiences in terms of their success and failure. For example, under the Bhiwandhi Electricity Distribution Franchise Model in Maharashtra, bidders for the DF contract were required to base their financial bids on a minimum 30 percent reduction in distribution losses and 33 percent increase in collection efficiency by the end of a ten-year contract period, which, in combination with long-term capacity building strategies to reduce commercial losses and improve consumer satisfaction, resulted in a 61.3 percent reduction in AT&C losses in 2005-06 and 25 percent in 2015-16. Similarly, in Odisha in 2013, the Central Electricity Supply Utility of Odisha carried out DFs in fourteen divisions under its license area, which were operated by three private companies awarded 5-year contracts under the IBF-IRS model. Given the short-term nature of this particular DF model, improvement in performance proved to be a cumbersome endeavor, yet losses nonetheless declined about 4-15 percent within three years of operation, with one of the three companies achieving the most loss reduction due to a set of complementary innovative practices, including (1) using software networking planning tools, (2) installing GPS-based spot billing machines and real-time phone-based metering reading, and (3) establishing 24x7 customer care centers and a web-based application for new service connections. In contrast, DF models implemented in Bihar and Uttar Pradesh have largely failed, in large part due to widespread resistance from utility employees and lack of baseline political will and buy-in to the DF model among incumbent public employees (Gupta [2016]). Moreover, the model has the potential to fail in cases in which a franchiser shirks on its responsibilities or carries out load shedding without proper communication and expectation management with consumers, likely resulting in customers blaming the private agent rather than the public one (Anand and Sambit [2009], Gupta [2016]). As discussed in a report by the Task Force for the Planning Commission of the Government of India, "the Franchisee Model is essentially a sub-contract for discharging the O&M obligations of the Discoms. The franchisee is not regulated by the SERC…all legal obligations continue to remain with the Discom while actual control over the distribution business is passed onto the franchisee" (Government of India [2012]). Given this, successful implementation of the model is partially contingent on carefully designed strategies for smooth transition to a new management structure.

While this DF model has, in a number of cases, succeeded at dramatically decreasing AT&C losses and increasing the quality of electricity services in different states throughout India, the various models are largely clustered under an overarching categorization of "Urban Franchises," given a general absence in their extension to rural areas. As it currently stands, the DF model "is not adequate when significant new investment in electrification is necessary" (Pérez-Arriaga et al [forthcoming]). Another existing model that tries to fill the gap in access for rural areas is called a "Rural Franchise," which can be either arranged as (1) collection-based revenue franchises, (2) rural electric cooperative societies that are self managed, or (3) rural electric cooperative societies that are operated through contracting (P-Manifold Business Solutions [2012]). The cooperative model is expanded upon in the following section.

4.2.2 Case Study of an Existing Model: Rural Cooperative

"… at the UN Conference on Sustainable Development (Rio+20) which took place in June 2012, [the following theme was highlighted]: cooperatives as drivers of sustainable development, social inclusion, and poverty reduction…cooperatives offer an interesting socio-economic business model for helping to overcome the lack of institutions and policy, and the lack of enterprises, organization, and human capacity, [thus enabling] the poor to be able to afford modern renewable energy by actually organizing and paying for renewables themselves."

- ILO [2013]

Drawing from the National Rural Electric Cooperative Association of the United States (NRECA), a pioneer of the rural cooperative model for accelerating electricity access across the world, an electric cooperative or EC can be defined as a "(1) private, independent, non-profit electric utility business; (2) [with assets that are] owned by the customers they serve; (3) incorporated under the laws of the states in which they operate; (4) established to provide at-cost electric service; and (5) governed by a board of directors elected from the membership which sets policies and procedures that are implemented by the cooperatives management" (NRECA [2018]). Over the last 150 years since the first cooperative model was inaugurated, rural cooperatives have strived to integrate long term sustainable development motivations and philosophy into their business operations, finding common ground between social, environmental, and economic needs. Moreover, as member based and adaptive organizations, rural cooperatives are designed to promote democratic and equitable participation; reflect the context-specific values and needs of local communities; streamline access to commercial services and business training for participants in the model; and react in a resilient manner to crises or changes in the marketplace or environment (ILO [2013]). The decentralized structure of rural cooperatives provides a platform for community participation, empowerment and direct accountability in the management and delivery of energy services, which arguably improves the social sustainability and efficacy of this business model (CORE [2008]; Barnes et al [1997]) and enables the "demystification" of electricity to user groups who previously misunderstood the distinction between technical losses and pilferage (Yadoo et al [2010]). Given their ability to "mobilize their members and the general public through advocacy, information sharing, and education and training" (ILO [2013]), the rural cooperative model holds an enormous amount of potential to address and overcome a number of the trust, reciprocity, myopic-thinking, bounded rationality, and information-related cognitive biases highlighted earlier in this chapter and previous chapters. At the same time, however, it is a difficult model to scale to an entire state or country.

The cooperative business model has reached innumerable people worldwide to date, through various arrangements in different development contexts. In particular, these cooperative models vary in size, scale, and type, ranging from cooperatively-owned micro hydropower plants that both serve small villages and sell surplus power back to the national grid and SMEs, to energy hubs that provide rural energy consumers with access to cheap, safe, clean cooking fuel and also operate as information and training centers. Furthermore, larger scale cooperative models include full-scale rural electrification cooperatives and self-sufficient bioenergy villages that provide power to rural areas that are neglected by utilities that worry about the financial viability of extending access to remote regions (ILO [2013]). For example, to provide a few scenarios of these variable cooperative models, in Brazil there are 126 rural electricity cooperatives providing power to over three million customers (ANEEL [2018]), whereas in the Philippines, the majority of rural areas rely on electric cooperatives for electricity access (World Bank [2013]). A brief number of concrete case studies of rural cooperative models around the world are presented in the following boxes.

Box 4.1

Cooperatives in Costa Rica and Bolivia

In the early 1960s, rural cooperatives in Costa Rica were able to establish a rural grid with long-term capital from USAID and the Inter-American Development Bank, setting a very early precedent for this model for other countries to follow. Similarly, since 1962, NRECA International has worked to establish a number of rural electrification projects throughout Bolivia, including the Cooperativa de Rural de Electrificacion Ltda (CRE), the world's current largest rural electrification cooperative serving 600,000 consumer members. Furthermore, in 2002, NRECA undertook the Alternative Development Program (ADEP) in northern La Paz to implement a comprehensive rural electrification program focused on expansion as a means to ameliorate agricultural and rural business performance for rural customers.

Source: NRECA [2018]; Barnes et al [1997]

Box 4.2

Cooperatives in Bangladesh

In 1978, only about 13000 citizens had electricity access in Bangladesh and now this number is approximately 68 million, with evidence that the average annual income of households with electricity access is 126 percent higher than those without access. The success of this initiative largely dates back to the creation of the Rural Electrification Board (REB) in 1997, which took over the responsibility of rural electrification from the Bangladesh Power Development Board and partnered with rural communities to create local electric cooperatives called Palli Bidyut Samities (PBSs), of which there are now about 70 employing 16000 people. While the PBSs are independent and privately owned, they are nonetheless under the direct regulatory purview of the REB: the PRBs design electrification master plans for their operational areas with integrated decision-making from the elected governing bodies and rural consumers, and submit their plans to the REB, which assesses the retail tariff's ability to cover costs for operation, maintenance, depreciation, and financing; monitors the financial sustainability, procurement processes, and management effectiveness of the PBSs; and issues contracts for annual performance targets that commit to increase revenues, decrease system losses, and improve the number of new connections based on the previous year's milestones. Moreover, the REB offers many additional forms of support and assistance to the PBSs, for example, through the provision of training services, support in O&M activities and procurement of funds, establishing relationships with energy utilities and other stakeholders, conducting elections, subsidizing financing through low-interest loans with long repayment periods, and negotiating subsidized rates at which the PBSs can purchase power from the national grid. Furthermore, for up to six years of a cooperative's start-up period, if it is making losses, the REB transfers direct subsidies. As a result of efforts to advance this cooperative model, distribution losses within PBS areas are as low as 10-15% compared to 30-35% for the national utility, collection rates are very high at 96% and 170000 irrigation pumping stations and 47650 villages receive electricity supply as a result of the PBSs' installation of 219,006 km of distribution lines.

Source: CORE [2008]; GNESD [2007]; REB [2017]; Yadoo et al [2010]; UNDP [2009]

Box 4.3

Cooperatives in Nepal: NACEUN

Back in 2002, the former Chairman of the Nepal Electricity Authority (NEA), which was registered as a commercial and for-profit entity, understood that the NEA was facing a number of core obstacles that constrained progress in rural electrification, including difficulties in mobilizing capital and controlling the theft of electricity. In order to overcome these barriers, policymakers looked to other sectors for direction and took note of Nepal's long history of successful community-based organizations (CBOs) that work to provide social services and public services. This shift in direction culminated into the Nepal Community Electricity Distribution Bylaw, which allows any cooperatives to buy bulk electricity from the grid and retail it amongst users and implement community-led rural electrification infrastructure construction. Under this arrangement, a new "creative relationship" between the state, private sector, and local communities was established, in which the "NEA provides up to 80% of the capital investment, communities contribute at least 20% of the total cost of grid extension via labor, household donations, bank loans…or grants from the local village and district development committees" and the CBOs bear responsibility for any electricity theft occurring in their service area. In 2006, these cooperatives grew vastly and conglomerated under the National Association of Community Electricity Users in Nepal (NACEUN) to facilitate focused attention and efforts on CBO-led electrification. Once CBOs have formally registered as cooperatives in their network, they can charge households an initial connection fee for in-house and other basic wiring, as well as a meter, and thereafter provide the services at the tariff rates set by the NEA for rural areas. The CBOs are further allowed to subsidize their poorest members if they so choose and work with microfinance institutions to distribute loans to members in order to advance productive uses of electricity or use the profits generated from electricity sales to provide micro-credit to members for small-scale income generating activities.

This model has proven to be highly successful in Nepal, with an acceleration in the rate and transparency of the rural electrification process, dramatic improvements in system losses, and reduction in theft in rural areas. Moreover, this approach has drastically reduced costs through a number of channels. For example, cooperatives expand at lower cost than similar extensions that were financed by multilateral banks due to less corruption and localized use of human capital and resources.

Source: Yadoo et al [2010]

Conditions for the Success of the Rural Cooperative Model

"Cooperatives should be treated in accordance with national law and practice and on terms no less favorable than those accorded to other forms of enterprise and social organization. Governments should introduce support measures, where appropriate, for the activities of cooperatives that meet specific social and public policy outcomes, such as employment promotion or the development of activities benefitting disadvantaged groups or regions. Such measures could include among others and in so far as possible, tax benefits, loans, grants, access to public works programs, and special procurement provisions." – ILO [2002]

While these aforementioned case studies have largely been highly successful in enabling the energy poor to access affordable and reliable electricity, there are other attempts at extending the rural cooperative model that have not performed well. As an example, in India, the cooperative system largely failed given that the Cooperative Societies Act, established in the 1950s, mandated that the government own a share of every cooperative – a fundamental violation of core principles of cooperatives concerning members' autonomous ownership and control. Thus, generally, in order for the cooperative system to work well, there need to be systems in place to prevent harmful influence of external political forces (NRECA [2018]). In particular, ILO [2013] highlights the following four core tenants of a successful cooperative:

1. Appropriate legal and policy frameworks for encouraging the sustainable development and growth of a cooperative, such as specific loan or guarantee schemes for cooperatives;
2. Respect for the autonomous ownership of the cooperative by the members;

3. Effective regulation that aligns with the scope, scale, and nature of the cooperatives' activities; and
4. Streamlined access to auxiliary services to improve the cooperatives' business viability and capacity to create productive and income-generating activities.

Effective public-private partnerships (PPPs) are arguably important enablers of progress toward achieving the objectives that successful rural cooperative models strive for, including providing utilities and electricity services that complement electricity distribution provided by the state. While the entire burden of provision to rural areas should not fall on the shoulders of rural cooperatives in lieu of the state carrying out its obligation to provide energy to all its citizens, the cooperative model is nonetheless highly effective in areas where for-profit enterprises, urban or peri-urban distribution franchises, or other private arrangements do not anticipate an ability to be financially sustainable (ILO [2013]. Well coordinated PPPs hold an enormous amount of potential to leverage and combine the individual strengths of these distribution business models that span the urban to rural spectrum of access in order to spread the risk and responsibility across numerous entities, while enabling a more localized and pro-poor system of energy provision. This latter point serves as a core underlying motivation for the concept model presented in the following section, namely the Energy Company of the Future (ECoF), which is an active and ongoing area of research endeavor carried out by the MIT-Comillas Universal Energy Access Lab.

4.2.3 Concept Model: Energy Company of the Future (ECoF)[49]

"…the heart of the electrification deficit is in the distribution activity. Incumbent distributors devote most of their efforts to grid extension, struggling with deteriorating assets and quality of service, theft and unpaid bills, poor reputation among consumers, and financial survival, while paying little attention to actual consumer needs. There is typically no strategy to move consumers from the lower access tiers to full access, either on or off-grid, nor to coordinate electrification planning with overall economic planning to ensure an economic return on electrification investments, with associated growth in demand…[nonetheless there are] multiple possibilities for innovation in management, technology, regulation, and consumer engagement, in particular for the last mile, where the direct interaction with the end consumers takes place" – Pérez-Arriaga et al [forthcoming]

The ECoF is structured around a concept of an enhanced and integrated distribution utility that is characterized by the following key set of elements, many of which draw from and try to build upon the strengths of existing grid and off-grid business models in both the public and private sphere:

1. The ECoF will operate under a zonal or territorial concession, in which it is obligated to supply electricity to all existing and potential customers in a particular territory, through any combination of electrification modes – from grid connections and mini-grids to stand-alone systems and battery charging – and is managed through various forms of partnerships with existing organizations, either

[49] This section encompasses active, ongoing work by the MIT/Comillas Universal Energy Access Lab, in collaboration with the Shell Foundation. Details of the concept model can be found in Pérez-Arriaga et al [2018 – forthcoming].

through the establishment of a consortium of local companies or the formal arrangement of a PPP. For example, off-grid solutions can be provided by the distribution company, or outsourced through partnership arrangements with franchised developers, independent private developers, or rural cooperative associations. Moreover, the regulation of this proposed company would mandate a form of regulatory or accounting separation between the "infrastructure" side of the company and the "retail" side, where the former is responsible for the quality of physical service provided to consumers and the latter side is responsible for metering, billing, reduction of theft, and other forms of activities around consumer engagement, such as searching for anchor loads or facilitating access to income-generating activities and business training. Distribution franchises, rural cooperatives, or other outsourced local partner groups would largely work on the retail side given their local expertise, experience, and pre-established trust in communities.

a. The distribution side: the distribution side or "infrastructure" component of the ECoF would (i) focus its activities and work on developing the system operation in the zonal or territorial concession service area; (ii) make a dynamic electrification plan that specifies between electrification modes at different points in time (using network planning software such as REM) – including transitions for consumers between off grid and grid access – and sets service quality targets as mandated by the respective regulatory authority; and (iii) build, maintain, and operate the main grid and mini-grids "under the regulated conditions of grid compatibility, quality of service, tariffs, and subsidization" with potential formal partnerships for coordinated action with local mini-grid developers.

b. The retail side: a large portion of the innovation behind this enhanced distribution company lies on the retail side, which aims to establish stronger, transparent, and more direct interactions with consumers through a combination of ICT-based communication mechanisms as well as complementary ground-level capacity building in cooperation with existing local organizations. It is within this retail side that numerous creatively crafted nudge behavioral design tactics can be carefully integrated and experimented with to assess the more effective choice architecture to incorporate into the business model.

2. As alluded to in the previous point, the ECoF aims to reverse and fix the longstanding damaged relationship between consumers and distribution utilities in many LIDCs by creating a more consumer-centric approach in the business model. In particular, the ECoF will draw from the case studies and insights laid out throughout this thesis – from the nuanced considerations of socioeconomic, behavioral, and technical factors that influence WTP and ATP across their variable definitions and closely related nudge interventions, to the promising technological developments related to digital finance, smart two-

way communication systems, and e-based government-citizen feedback and participation systems – to develop a set of human factors strategies for positively changing distribution activities in the grid and off-grid service areas of the zonal concession. These strategies include, but are not limited to:

a. Provision of effective and immediate communication channels between service providers and consumers, with a well-staffed and 24-hour call center and consumer attention offices that are both fixed and mobile. For example, such communication can include text message notifications about scheduled outages and their estimated duration that are sent in advance to consumers, as well as other framed information strategies such as those laid out in Figures 4.1-3 that can apply and be adapted to both grid and off-grid electricity services provided by the ECoF.

b. Establishment of numerous technology-facilitated interventions, such as additional sensing and control technologies that are applied to individual consumption; systems that more effectively predict, prevent, detect, and reduce electricity theft; decentralized blockchain platforms (see the Annex) and digital payment systems that can both increase the convenience of payment and ATP for liquidity constrained consumers, while creating data for the ECoF to better understand consumer behavior and decision-making. For example, with regards to the additional sensing technologies and smart metering, the salient features embedded in smart feedback systems have been shown to enable consumers to better manage and understand their energy consumption, thereby improving their comprehension of their own mental accounting and budgeting for bills. Moreover, with regards to the ultimate point about digital payment systems, machine learning models can be leveraged to predict which customers are more or less likely to keep up with payments, as well as analyze factors that affect different types of consumers' ATP in order to better refine business processes and test the best ways in which to reach more consumers.[50]

c. Implementation of ground-level consumer engagement activities, such as working with local networks of trusted individuals who know a community well (for example, rural cooperatives) to spread information about the ECoF's activities, establishing literacy and training centers or professional education activities, and running so-called "connection camps" where company employees or associated retailing partners can send well-respected staff to neighborhoods to

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[50] Simpa Networks in India, in partnership with MasterCard and researchers from IBM and Innovations for Poverty Action at Yale, conducted this exact experiment a few years ago. In particular, the PAYG solar company used historical customer payment behavior data to predict which new applicants would be better suited for their standalone solar power systems program, finding that customers who made three or fewer payments in the first 180 days of obtaining the system had a 60 percent chance of losing the system. The machine learning algorithm developed in this project to approve customers has the potential to decrease delayed payments by 12.5-18 percent while still allowing for the acceptance of about 70 percent of the total customer pool (Gerard et al [2015]).

assist customers without connections with the process and demystify safety and reliability aspects (Pérez-Arriaga et al [forthcoming]).

Ultimately, this high-level approach to the design and conceptual framework of the ECoF has enormous potential to help accelerate, formalize, and strengthen the coordination between the currently disparate approaches to grid and off-grid electrification in LIDCs. The new pro-poor business model adds value from numerous angles, including the ways in which it aims to minimize waste and duplication, ensure the grid compatibility of microgrids and stable presence of renewables in the distribution grid, and focus its operations on a variety of means to enhance consumer trust and reciprocity. Nonetheless, the ECoF concept it is still in its early stages of development and carries with it a large number of uncertain political and regulatory implementation challenges and lingering questions. In the following section, I discuss areas of future work relevant to both this proposed new business model, as well as to other topics that have been covered throughout this thesis.

4.3 Future Work

While 2030 may seem to be in the distant future, the clock is nonetheless ticking rapidly, with an increasing number of experts expressing doubt and concern over the ability to achieve the goal of universal access to affordable and reliable electricity within the specified timeline. As such, there is an actively growing body of research and literature that is motivated by an all-encompassing objective to both better understand the nuanced set of interrelated and complex constraints that preempt access at a large scale in a financially-sustainable manner and, furthermore, develop effective and empirically-backed interventions that either aim to break existing negative feedback loops or generate new positive feedback mechanisms in the different areas of grid and off-grid distribution planning. Even though I have already briefly highlighted various research proposals and areas of further work in previous chapters, these recommendations were largely biased toward consumers and demand-side problems and research questions, such as testing the causality of cognitive mechanisms that influence both the ATP and WTP of electricity consumers. In the remainder of this section, I present a set of potential questions for future research that further augment the demand-side proposals while also bringing attention to supply-side matters and questions around enforcement, accountability, coordinated development projects, and policy and regulatory design for the new ECoF model.

4.3.1 Demand-Side

1. To what extent is the price elasticity (or inelasticity) of demand of consumers in LIDCs affected by: (i) more salient, accessible, and transparent information about tariff and subsidy design; (ii) personalized feedback on consumption patterns; (iii) enhanced trust-building and organizational performance; (iv) improved reliability and quality of electricity services; and (v) targeted

information about savings obtained by switching between fuel and technology options?

a. How do different socioeconomic, behavioral, and technical factors affect consumers' decisions about which supply technologies to take up?

b. What factors influence consumers' decisions to connect to multiple systems simultaneously?

c. To what extent are these connections serving as complementary or substitute technologies (Lee et al [2017])? Do consumers utilize different connections for different purposes, and if so, why?

2. What factors affect consumer preferences and decision-making about appliance ownership?

a. Would an extension of innovative financing schemes, such as PAYG, close gaps between households' current appliance ownership and their future aspirations?

b. To what extent is household adoption (or lack thereof) of different appliances influenced by social or peer network efforts? To what extent is it affected by the level of trust in the electricity service provider or product vendor?

3. In what ways may targeted subsidies, conditional, or unconditional cash transfers specific to energy-related expenditures impact consumer decision-making and attitudes?

4. What factors enable the success of an energy-conservation or payment-behavior "nudge" or behavioral design intervention targeted at consumers and what factors cause a backfire effect?

4.3.2 Supply-Side

1. In what ways can external donors or utilities strengthen the governance of electrification programs in order to overcome challenges of corruption and fund leakage (Lee et al [2017])?

a. To what extent can nudge strategies be applied to potentially corrupt politicians, regulators, or utility service providers to address issues relating to transparent and honorable enforcement of policies or business operations? Which nudge strategies or other forms of punitive or reward-based incentive mechanisms would work most effectively in traditionally corrupt or politically volatile environments?

b. How can technological interventions be leveraged to not only monitor the behavior and compliance of consumers, but also that of the electricity providers?

2. In what ways would a redefinition of the metrics utilized to measure access and reliability in countries, such as India, change the ways in which planning agencies prioritize and communicate

electrification strategies?

   a. To what extent should governments emphasize access of electricity vs. improving the quality of existing infrastructure over both short and long-run time horizons? How do the relative costs and benefits of access vs. reliability compare on both micro and macroeconomic scales across different time periods?

4.3.3 Institutional Coordination

1. Drawing directly from Lee at al [2017]: “what are the spillover impacts of electrification? How does the design of an electrification program influence the spillovers that are generated? For example, is there something different about a ‘mass electrification’ program compared to a more gradual…electrification process?”

   a. In what ways can existing institutions develop improved coordination mechanisms in order to maximize spillover between development goals and benefits? For example, what complementary strategies and inputs can ministries or agencies related to energy, water, agriculture, and rural employment or welfare schemes implement to achieve simultaneous objectives and use coordinated resources to reduce redundancies?

2. Are there examples of effective inter or intra-ministerial or regional coordination mechanisms in any LIDCs that aim to concurrently address numerous development objectives in a single program or intervention design? If so, in what ways have these programs affected the prevalence of productive uses of electricity and the overall income-generating capabilities of consumers across time?

3. In what ways can private sector actors develop partnerships with government agencies to enhance coordination and complementarity between development objectives, such as access to clean energy, water, transport, health, etc.?

4.3.4 Policy and Regulatory Design for the ECoF

1. What are the most important social and political barriers to the successful adoption of this new business model in different settings?

   a. To what extent will citizen or incumbent utility employees’ attitudes toward privatization enable or disable the successful implementation of the ECoF? What strategies could the ECoF adopt to mitigate these concerns and manage both consumers’ and public workers’ expectations effectively through the design of its governance structure?

   b. In what ways may a segmentation of different kinds of electricity services – such as different electrification modes, each with its own tariff and reliability requirement – affect consumers' perception of the ECoF? How can the ECoF build acceptance and trust in this approach with its stakeholders and partners?

   c. What forms of incentives can the ECoF design to encourage good performance and discourage any form of decision-making that favors one group over another? In what ways can the ECoF structure itself to ensure the honorable enforcement of performance-based remuneration incentives?

2. What regulatory, financial, and technical strategies are necessary in order to address or reduce challenges related to the persistent viability gap? How can the ECoF gradually phase its customers to accept paying for more cost-reflective tariffs?

   a. What strategies should the ECoF adopt to preempt opportunistic political interference by politicians seeking to be elected and spreading falsities about free electricity to less educated consumers?

3. In what ways can the ECoF effectively partner with ICT operators – namely telecommunications and internet service providers – in order to maximize its reach and efficacy in geographies with worse access to or adoption of mobile phones and digital payment services?

4. How can the ECoF contribute to enabling improved inter or intra-ministerial or regional coordination to enhance simultaneous achievement of development goals and develop extensive opportunities for productive uses of electricity that are sustainable over a long period of time?

4.4 Conclusion

"...Too often, planners confront this electricity access gap by increasing supply without attention to how consumers actually use and pay for electricity. A lasting solution is far more complicated than that."
- Odarno [2017]

The provision of affordable and reliable electricity services to every global citizen is a daunting task that can often feel like an overwhelmingly wicked problem. The further and deeper that one digs into understanding the complex and nuanced network of heavily interrelated social, political, financial, regulatory, historical, behavioral, and cultural barriers to access across urban and rural geographies around the world, the more complex the challenge becomes. In particular, this back-tracking process through the web of negative feedback loops that characterize electricity distribution reveals that, at a fundamental level, the challenge of universal access is arguably obfuscated by a lack of universal *understanding,* agreement, and public communication about different sets of measurements that are central to conversations around access. These parameters are difficult to quantify and are consequently applied in disaggregated and often poorly structured ways by policymakers, researchers, and practitioners working in both grid and off-grid sectors. Examples of these concepts and associated metrics include energy poverty, access, reliability, utility, welfare, willingness-to-pay, ability-to-pay, and cost of non-served energy. Given the immense difficulties involved with quantifying these variables, – in simultaneity with the oft time-pressured mandate to design and implement various top-down planning models and cost-effective policies, – actors working in the sector have frequently resorted to oversimplified, rational, and binary characterizations. However, these simplified measurements often fail to adequately represent the actual, ground-level realities of the energy poor consumers. This issue of measurement is by no means unique to the energy sector and is, in and of itself, another wicked challenge that transcends across essentially every type of technology and policy problem. However, its prevalence in the energy sector – particularly in the context of low income and institutionally weak countries – has profound implications, including spiraling forms of unintended consequences and rippling effects on the short and long-run belief systems and decision-making of stakeholders within the sector. These affected stakeholders can range from the politicians and regulators who create and communicate policies on access and reliability and the public or private electricity service providers, to the grid and off-grid technology and technoeconomic planning tool developers and ultimate electricity consumers.

This thesis and the series of essays embedded within it have focused in large part on the latter group of stakeholders, namely the end users of varying electricity services in low-income settings, with a considerable amount of attention dedicated to India as an overarching case example. In particular, I presented an intensive analysis of electricity distribution challenges in India with an overall aim to demonstrate the gaps in understanding about energy poverty, access, reliability, and welfare, among other indicators, and the nuanced ways in which these concepts are manifest in the institutional, regulatory, financial, socioeconomic, sociopolitical, and technological context of the distribution sector. Thereafter, I extended this form of questioning to settings beyond India, with an explicit motivation to both complicate and expand comprehension of the ways in which willingness and ability-to-pay, as well as other associated measurements such as welfare, are defined, measured, and influenced by behavioral, technical, and socioeconomic parameters. Ultimately, I concluded with a final essay on mechanisms and strategies that future pro-poor and human-centered business models and policies can adopt, experiment with, and integrate into comprehensive grid and off-grid planning in such a way that moves closer to realistically reflecting the true complexity of these metrics in low access settings.

Complete universal understanding and agreement on the essential ideas, concepts, and measurements that underpin the discourse around universal access may continue to be beyond our grasp for decades to come, if ever. However, innumerable actors that work across various levels of the energy sector have come to a consensus that the traditional approach and ways of thinking about the problem need to change in a direction that moves increasingly toward pro-poor, multi-tier frameworks of understanding and planning strategies that enable the participation and agency of consumers. The active work that has emerged in recent years on this line of questioning and rethinking, such as those highlighted throughout this thesis, signals that a shift in the paradigm is on the horizon. The sun may continue to rise and set over this horizon for years until universal and reliable access to electricity is achieved, yet with each new day, more light will continue to shine on the dark cracks and crevices the exist throughout the system, bringing us closer to not only mending the broken pieces that exist in the structure, but also fundamentally changing its foundation to become stronger, cohesive, adaptive, and resilient.

Annex

Case Study on Blockchain and Rural Electrification

Overview of Blockchain

Over the last couple of years, blockchain or the underlying decentralized architecture behind Bitcoin, has gained enormous traction among research institutions, public, and private sector actors due to its extensive potential applications beyond fin-tech. A technology claimed to represent the "second generation of the Internet" (Tapscott and Tapscott [2016]), blockchain is defined as a crowd-managed and distributed database or digital time-stamped ledger that enables direct, immutable, peer-to-peer transactions without the need for a trusted third party mediator. Connected machines and validating nodes in this distributed ledger operate through agreed upon trust protocols or consensus algorithms that allow participating nodes to work together under a coherent set of rules and survive, even if some members fail (Seibold and Samman [2016]). What ostensibly ensues from this is a highly efficient, scalable, democratic, transparent, and tamper-proof infrastructure for executing transactions and contracts between parties, resulting in significant reductions in transaction costs and improved trust in record-keeping, thus reducing counterparty risk. While blockchain is a nascent technology with a wide range of uncertainties and challenges, smart contracts[51] and automated audits nonetheless have huge potential to become embedded across industries, from financial service, telecommunications, and tech/IoT applications to energy, health, and the public sector.

Blockchain and Energy

There are currently numerous actors working and experimenting in the space of blockchain and energy around the world, including in emerging economies:

Bankymoon (South Africa)

In partnership with ConsenSys[52] and IBM, this South African bitcoin startup has built a blockchain smart metering solution for power and utility grids. Consumers can top-up smart prepaid meters by using digital currencies and the payment would be settled automatically through mechanized smart contracts, which help to preclude late payments and decrease debts. This solution is meant to benefit the largely unbanked populations by bypassing traditional financial institutions and credit card constraints. This idea is being tested at schools that have been provided smart energy meters (Buntinx [2016]).

Grid Singularity

This Vienna-based company founded by some of Ethereum's[53] core team members is experimenting with blockchain to validate energy transactions, with a focus on increasing the security of pay-as-you-go systems for solar in low income and developing countries (for example, M-KOPA in Kenya) (Lacey [2016]).

Brooklyn Microgrid

[51] Smart contracts are applications that run exactly as programmed without any possibility of downtime, censorship, fraud, or third party interference.
[52] ConsenSys is a venture production studio building decentralized applications and developer and end-user tools for blockchain ecosystems, with a specific focus on Ethereum.
[53] Ethereum is an open-source, public, blockchain-based computing platform featuring smart contract functionalities.

The Brooklyn Microgrid, operated by TransActive Grid, LO3 Energy, and ConsenSys, represents an emerging IoT-enabled community managed energy system, with a hardware component of smart meters and software component that uses blockchain and smart contracts to allow for peer-to-peer (P2P) electricity transactions between neighbors' smart meter wallets. LO3 has already built two nodes that are assembling data on consumption and generation across the micro-grid and putting it into the blockchain (Lacey [2016]).

Beyond these existing organizations, there are some more conceptual and hypothetical ideas that merit further discussion. For example, the rise of PAYG business models combined with the security provided by blockchain can potentially allow for asset-backed lending to the poor. For example, Price [2016] utilizes the case study of M-KOPA in Kenya, Uganda, and Tanzania to discuss how its PAYG model for SHSs and portfolio of customer accounts and digital flows present an opportunity: "if the company's consumers could establish a digital track record of repayment [and thus credit history], the collection of customer receivables, or commitments of future payments, might be used as an asset against which M-KOPA itself could take out a loan. If M-KOPA's accounts receivable could qualify as high quality collateral, local commercial banks could make loans for inventory and expand the company's ability to extend credit to low-income customers. Asset-backed lending to the poor could emerge as a bankable proposition." M-KOPA is in fact currently building credit histories for a large number of customers, in partnership with Kenya's Credit Reference Bureau.

Blockchain and Rural Electrification Opportunities in India

While financial, socioeconomic, political and institutional bottlenecks in India's infrastructure for electricity access are abound, there may exist pockets of opportunity for helping to clear some of these roadblocks through block-chained enabled technology. In particular, two key areas that warrant in-depth exploration include (1) reducing (actual and perceived) risk for investors and (2) facilitating bankability and financial inclusion for rural villagers.

Risk to Investors and Potential Blockchain Solutions

There are innumerable factors that contribute to the risk aversion of investors and entrepreneurs considering operating in India's off-grid markets (Singh and Mitra [2010]). For example, unexpected grid extensions - without complementary regulation - can undermine investments made in distributed renewable energy systems in rural settings and persistent viability gaps weaken companies' ability to recover costs (Pérez-Arriaga [2017]). Moreover, there is widespread uncertainty with regards to guaranteed, timely payment and receipt of subsidies for solar from the government to micro-grid enterprises (Jaffer [2017]), as well as bureaucratic delays in business registration and time consuming contract enforcement procedures (Doukas and Ballesteros [2015]).

Blockchain and its smart contract applications hold potential to address some of these challenges, in particular the latter ones. For example, through Ethereum's decentralized platform for running smart contracts (which run exactly as programmed without the possibility of downtime, censorship, fraud, or third party interference), actors can create contracts that hold or disperse a contributor's money on a given date or when a goal is reached. Based upon the outcome and conditions programmed into the contract, the funds will either be released or returned to the project owners, without the need for a third-party arbitrator. In the case of India, the actors are the government officials and micro-grid enterprises, and the contract is for the dispersion of subsidies between these two. This application can, in theory, improve the timeliness of payments, reduce bureaucratic red tape (Lee et al. [2016b]), and create a permanent ledger to track transactions. The blockchain could additionally provide a platform for tamper-proof tracking and logging of licenses, thereby eliminating redundancies to improve the business and investment environment (Doukas and Ballesteros [2015]). These blockchain applications arguably fit in well with some of the ongoing e-governance, e-procurement, and digital financial transfer platforms rolled out by the Indian government, as described in Chapter 2.

Financial Inclusion and Potential Blockchain Solutions

There are also a host of factors that preempt financial inclusivity for rural villagers, many of which ultimately are rooted in issues of trust, asymmetric information, and a lack of capacity building. For example, lenders often do not see investors (and projects) that serve villagers in need of distributed energy as bankable and have higher risk perceptions, thus making them reluctant to finance projects and products that service this population (Doukas and Ballesteros [2015]). Furthermore, banks are often inadequately educated with regards to government policies on subsidies for solar or lack the capacity to follow up on whether a firm is meeting the terms of agreement with customers on ensuring after-sales service; the lack of this can often lead to customers defaulting on loan repayments and failing to build strong credit histories (Singh [2016b]).

There are numerous business models, sometimes in partnership with local microfinance and other banking institutions and mobile money systems, which aim to mitigate some of the risk factors surrounding financial inclusion. The particular model that may hold the most potential to formally build credit history and intersect with blockchain is the PAYG or progressive purchase model for isolated solar systems in partnership with companies, such as Simpa Networks or OMC Power (ADB [2013]). Opportunities that exist include the incorporation of a kill-switch, as well as creating a digital ledger of repayment. Moreover, in the context of India, there may be an interesting prospect to bring blockchain into some intersection between the India Stack's Aadhaar digital identity system and mobile-based payment systems in order to build villagers' credit history and unlock increased access to financing. Recently, the state of Maharashtra has already started to experiment with a blockchain-integrated platform to secure government data, including land ownership records (Reese [2018]). As the regulatory environment becomes clearer and more well defined with regards to blockchain technologies in India, it is possible that such forms of record-keeping and transaction monitoring will spillover to other state governments and energy businesses.

Perspectives from India

In January 2017, our research group held a number of meetings with different stakeholders, including IBM Research, Avanti Finance, and IFMR Trust, to explore the potential for blockchain to intersect with the energy sector to address a number of the challenges related to electricity access. While each interviewee voiced some reservations about the technology and its legal and regulatory uncertainties, there was qualified consensus around its potential to intersect with the movement toward e-KYC, or e-based Know-Your-Customer platforms in India (Ananth [2017], Arya [2017], Thakkar [2017]). For example, Arya [2017] discussed how "the drive toward KYC could maybe intersect with blockchain, with linkages between microfinance institutions, local micro-grids, and customers, where payment patterns and history can be used to assess the credit history of customers...Chile has some program that assesses credit-worthiness based on ability to pay back utilities." Similarly, Thakkar [2017] talked about the ways in which the Avanti Rural Credit scheme of the Tata Trust builds off of the India Stack by linking bank account numbers to Aadhaar and disperses subsidies in this form, with validation through e-KYC. However, while these applications hold promise, there are a number of institutional and regulatory barriers and considerations that must be overcome - a topic which the government think-tank called Niti Aayog is gradually examining.

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