Title

Presumptions and Precarity: Probing Electricity Infrastructure

Author

Jacome, Veronica I

Publication Date

2020

Peer reviewed|Thesis/dissertation

Presumptions and Precarity: Probing Electricity Infrastructure

by

Veronica Jacome

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Energy and Resources

and the Designated Emphasis

in

Critical Theory

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Isha Ray, Chair
Professor Leonardo Arriola
Professor Michael Burawoy
Professor Michael Watts
Professor Catherine Wolfram

Spring 2020

Presumptions and Precarity: Probing Electricity Infrastructure

Abstract

Presumptions and Precarity: Probing Electricity Infrastructure

by

Veronica Jacome

Doctor of Philosophy in Energy and Resources

Designated Emphasis in Critical Theory

University of California, Berkeley

Professor Isha Ray, Chair

The international community has for decades tasked itself with worldwide "Development," broadly understood as a project to improve the human condition. Among development projects, electricity infrastructure has received an outsized amount of money and support. Despite this concerted effort, electricity development goals have been largely unrealized and huge disparities in electricity production and reliability persist worldwide. Infrastructure scholarship leans on an old global dichotomy: infrastructure in the Global South is marked by failures while in the North it is successful and taken-for-granted. Centralized grid systems of the Global North are characterized by cheap, constant, plentiful access, or "abundant" systems, while Global South services are characterized by expensive, erratic, absent access, or "constrained" systems. In the prevailing narrative, electricity providers, workers, and the users themselves, particularly those in sub-Saharan Africa, are to blame for failing electrical systems. By both scholars and policy-makers, users are often cast as "corrupt," "thieves," and "non-payers," whose behavior culminates in non-technical losses. This link between bad users and bad systems informs policy measures and technical interventions, but it has not been sufficiently justified. In this dissertation, I leverage the global energy dichotomy in order to move past oversimplified, prescriptive narratives.

The challenges of electricity development and inequality are compounded by an astounding array of disciplines required to understand them. This project uniquely synthesizes power system engineering, critical theory, and social science. I argue that social and material relations underpin electricity infrastructure, and use a Marxian understanding of these relations to explore the material conditions of "the grid" (i.e. voltage fluctuations, power outages, and intermittency) alongside the actors and actions they mediate and through which they are mediated. Ultimately, this work has implications for the interdisciplinary study of electricity, establishing important groundwork for understanding how vulnerabilities and opportunities

are spread, by whom and for whom, along "the grid."

Situated in electricity services in sub-Saharan Africa (SSA) and within "modern energy for all"—the international commitment to support electricity access in poor communities worldwide — this dissertation uses Unguja, Tanzania as a main site to investigate how contemporary assumptions about the value of electricity development impact inequalities. Specifically, it probes three key assumptions in contemporary electricity development – those of goodness, equity, and abundance – and explores related aspects: the evolution and fragmentation of authority and responsibility in the governance of electricity provision; the production of everyday life in constrained electricity systems (characterized by expensive, erratic, absent, and hyper-visible access); and the implications of using abundant grid systems as benchmarks for grid development today. Guided by a historical comparative lens, I use interviews, surveys, and two years of voltage monitoring to develop an ethnographically-grounded study of the social and material relations produced, and the responsibilities contained within, the Unguja grid.

In ***chapter one***, I offer an introduction to the political economy of grid development and provide a theoretical framework that guides the rest of the dissertation. In ***chapter two***, I explore equity as it relates to "modern energy for all," and specifically the rise of prepaid meters as the technical solutions to theft and mismanagement. I find that the rise in the prepaid meter represents a shift away from a provider- and user-centered relationship to a more overtly techno-human one, with new roles for Unguja residents. For the state-owned utility, a less visible, seemingly distant relationship with its customers emerged. Importantly, I find that although governmental and non-governmental institutions are, on average, more indebted to electric utilities, utilities and foreign donors (such as the World Bank and IMF) push prepaid meters more aggressively on residential users. Thus the responsibility for "unsuccessful" grids is discursively and actively falling on residential users, but so too are the vulnerabilities these constrained systems induce.

Chapters three and four probe the assumption of goodness in an electricity connection. Broadly, I ask: what life do constrained grids produce? In light of constrained grids, how do we interpret the quest of "modern energy for all?" By all accounts, the Unguja electric grid is a constrained system. Grid services in Unguja are considered highly unreliable, thus creating daily challenges for their relatively poor Zanzibari users. Nevertheless, technical experts in the area claim that "households can cope." Chapter three explores what residents are forced to cope with. I combine extensive empirical mapping of electricity quality with household surveys, showing that extreme voltage fluctuations result in dim lights at best and power outages and broken appliances at worst, denying many residents the expected benefits of access to electricity. Finally, in chapter four I explore residents' experiences with, and expectations of, their electricity services, and deliberately highlight their stories as they more broadly relate to a global development discourse on electricity infrastructure. I argue that perhaps expectations are being met because expectations are so low. This is a type of national politics that allows global development politics to ignore the precarious

vulnerabilities of unreliable services, in turn reinforcing the logic that "a little goes a long way."

This dissertation shows how assumptions in electricity development have served to misplace blame on, and helped spread new burdens and vulnerabilities in, SSA communities. It is guided by what I believe is the future of "modern energy for all"—constrained electric grids. Ultimately, I hope this project will spark a reckoning over the possible limits of contemporary electricity development and inform future policy decisions.

To Olga and Marc

Contents

List of Figures

List of Tables

Acknowledgments

These are so hard to write. Acknowledgements. You begin them only to realize how futile of an undertaking it is. To write acknowledgements for the sake of giving thanks or crediting folks who helped you along a seven-year journey is to know you are forgetting people. So if you happen to read this, know that the space between each word contains the names of those I did not mention, but who nevertheless deserve to be acknowledged.

I owe the biggest debt of gratitude to Zanzibaris, without whom this work would not have been possible. I thank them for generously welcoming me into their homes time and time again. ZECO Engineers Ali, Othman, and Said, and professor Aley Nassor offered me endless support and guidance in each and every visit. Phil, Ame, Safia, Nassor, Pam, Shirley, and Tia always made me feel like I had a family in Unguja.

In the first couple of years of my PhD at ERG, Dan Kammen, Duncan Callaway, and Kay Burns were there to make sure I was able explore my interests but never get lost in them. They provided me with institutional and emotional support that made possible my venturing out into the halls of other departments. Dan encouraged me to seek out geographers and always championed my work; Duncan provided a model for what academics should and can be: rigorous and thoughtful; and Kay provided me with absolutely everything.

The interdisciplinary depth and breadth of this work came from many a back-a-forth with my dissertation committee members. I owe a special thanks to Leo Arriola for introducing me to his kind and generous Africa Seminar Group. Outside of ERG, this was my Berkeley home. It was a pleasure to share ideas with Catherine Wolfram; she always saw the immense value in multi-disciplinary approaches. I am indebted to Micheal Watts, whose wisdom inspired me to take on electricity studies in radically new directions, and Michael Burawoy, who gave me a sophisticated approach to carry this work forward.

And finally there is Isha Ray –the most fabulously dedicated dissertation chair – who made all of this possible. Against her better judgement, she read electricity and Foucault for me. She deserves pages upon pages of acknowledgements, but for decorum's sake I leave her with a simple paragraph.

This work has been read and re-read by Katie Epstein and Megan Bowen. I thank them both for giving me the confidence I needed to get my ideas out. Derek O'leary has shown me that there is hope in academia, as long as we do not take ourselves so seriously – intellectuals, it seems, can be funny at times. Those in ERG, especially Michaelangelo Tabone, Zach Burt, Anaya Hall, Sophie Major, Ella Belfer, Grace Wu, Ranjit Deshmukh, Julia Szinai, Peter Worley, Yoshika Crider, Jess Goddard, and my 2013 cohort were my support system, they guided me through fieldwork and writing emails, helped me refine my ideas, cared for me in the hospital, during doctor's visits and post surgery, and finally, celebrated the end with me.

And of course, there are my family and friends outside of ERG's halls, in Venezuela, Chicago, Paris, and beyond, who have offered up the kind of love and unconditional support a PhD marathon requires. My wonderful parents, Olga and Marc, my brothers, Gabe and Dan, and their beautiful families, Peggy, Amy and the kids – they are my everything.

Chapter 1

Introduction

1.1 Introduction: Electricity Studies Transcending Multiple Geographies

One moment I was running down the hall, the next I was on the ground. The power had gone out in our neighborhood of Valencia, Venezuela and in the darkness I could not see the slick puddle. The impact my head made with the floor remains my first, most vivid experience with unreliable electricity. Reportedly, an incident at the Guri Dam had triggered the power outage. The fourth largest dam in the world, Guri once provided one-third of Venezuela's electricity. When construction took place or water levels became too low, rolling blackouts occurred. Now, the dam is barely functional. Though the Maduro government blames foreign sabotage for a March 2019 blackout that left more than 30 million Venezuelans in the dark, citizens are keenly aware of the local politics of infrastructure. The struggle between keeping the country's aging infrastructure afloat and the siphoning of public money for private gains is constitutive of the Venezuelan state.

Thousands of miles away and a decade after my fall, teaching physics in Songea, Tanzania, offered me another perspective on the world of electric wires and currents. There, I taught students the difference between electric potential and voltage, while simultaneously watching our school's donated computers gather dust, threatened by poor voltage quality from the centralized grid. At home, my lightbulbs and voltage stabilizers burned out regularly. And though I knew I was lucky to have electricity in a country whose rate of electrification is among the lowest in the world, it was difficult to pay electricity bills comparable to those in the US while living on a Tanzanian salary of $125 a month; like my neighbors, I chose to cook with a charcoal cookstove over my electric stove. My experience in Tanzania reinforced my view that assumptions about electricity development are culturally specific.

These two personal frames of reference inform the approach of the interdisciplinary study that follows. On the one hand, from Venezuela to Tanzania, I have come to know that electricity mediates social life and that when wedded to statecraft it can be used for personal and political gains that exacerbate inequalities. On the other hand, through physics, I am

invested in analyzing the physicality of these contexts: what techniques drive the placement of lines and the siting of transformers and power plants? How does this configuration impact outages? This project serves as a broad critique and interdisciplinary study of the interplay between energy and society.

I investigate the presumptions and precarity embedded in contemporary electricity development today by applying critical theory, social science research methods, and electric power systems monitoring. The crux of my argument is that a set of dialectical relations underpin electricity infrastructure. I use a Marxian understanding of these social and material relations to evaluate the physics of "the grid" (e.g. voltage fluctuations, power outages, and intermittency) alongside the actors and actions it mediates and through which it is mediated. Ultimately, this interdisciplinary energy studies establishes important groundwork for understanding how vulnerabilities and opportunities are spread, by whom, and for whom, along "the grid."

1.2 The Contradictory Nature of Electricity Development

Heralded as the "solution" to many of the world's challenges, electricity infrastructure development has garnered outsized attention and resources in the last decade. While the history of electricity development is rooted in industrialization and wartime economies, contemporary electricity development is feverishly advocated for on environmental and humanitarian grounds. Technical academic research as well as government and non-governmental climate reports promote increased reliance on electricity to reduce greenhouse gas emissions, a mission some refer to as "electrify everything" [152]. One heavily cited study concludes that significant reductions in greenhouse gas emissions require "widespread electrification of transportation and other sectors" [175], a conclusion supported separately by the International Energy Agency and by the United Nations [168]. The humanitarian perspective is captured by the mission of "modern energy for all;" non-governmental initiatives as well as foreign aid and foreign direct investment efforts are devoted to increasing electricity access to improve human living conditions in poor communities. Among the major efforts and flows of capital was a seven billion USD aid-package allocated in 2013 by the Obama administration to support electricity development in Africa. These billions were part of a broader state initiative called Power Africa, with a goal to "double electricity access in sub-Saharan Africa." [1]

Complicating this ambitious target is the reality that electricity services already tied to large aid development schemes have rarely been good or adequate for poor people. The majority of electricity connections in sub-Saharan Africa (SSA) are too costly and unstable, or provide too little power, to displace biomass fuels in homes (the latter being the epitome of a non-modern existence in today's technocratic age). Underscoring these realities is the United Nations' Sustainable Development Goal 7 (SDG 7). Its mission to spread "affordable,

[1] See https://www.usaid.gov/sites/default/files/documents/1860/power-africa-overview.pdf

reliable, sustainable, and modern energy for all" arose in contradistinction to people's lived experiences with unaffordable, unreliable, and unsustainable electricity services. Even more confusing than the insistence of poverty alleviation through systems historically unfriendly to poor people, is the question of who is set to benefit from these high-value initiatives. Explicitly called a form of "soft power" and "in contrast to US military muscle" – Power Africa encapsulates the contradictory nature of contemporary electricity development [94]. Fearing that the Trump administration might step back from the seven billion dollar deal, Herman J. Cohen (a former US Secretary for Africa) said "Under 'Power Africa', American investors can make good profits selling electric power to African utilities while also contributing to African development – a win-win situation" [5]. How and who "wins" is unclear. What we assume, however, is that behind these initiatives, large or small, asymmetrical power relations persist as capital accumulates, and everyday people become subject to the production and (re)production of unreliable and unaffordable systems.

This work is motivated by the contradictory nature of electricity development and the links between energy infrastructure, development, and environmental justice as I have come to understand them. While reflecting conditions of those in so-called modernized communities, mainly located in the northern hemisphere, the theories, practices, and techniques embedded in electricity development, tied to capitalist development, are themselves uneven and environmentally consequential. Situating my work in electricity services in Tanzania and within "modern energy for all", I investigate how contemporary assumptions about the value of electricity development impact inequalities. Specifically, I am interested in the relational processes that (re)produce socio-material conditions within electricity services characterized by expensive and erratic access. Guided by a rigorous understanding of the electric power system and critical social theory, this research contributes to the political economy of development and the environment, critical urban studies, and theories of the Global South.

1.3 Methodological Approach: An Anthropology of Modern Energy for All

> Anthropology, I argue, is a speculative and comparative inquiry into life's conditions and possibilities... [it] is not an optimistic discipline, secure in the belief that it is heralding a better future.... What we do offer is hope. It is the hope that seeks to turn every closure into an opening, every apparent end-point into a new beginning. Hope is the guarantor that life can carry on, of its continuity and sustainability, not just for some at the expense of others, but for everyone.
>
> Tim Ingold [82]

At the core of my research is an attunement towards everyday practices and their connection to world systems and knowledge. I attend to the historical and cultural context

through which "modern energy for all" discourses and practices operate. In this sense, I employ anthropology not so much as a discipline, but an ontology: a method of explanation of the links between culture and action, and between the material and the conceptual. Ideas and materiality matter, and anthropology successfully combines them. Thus, I take up Akhil Gupta's call for an anthropology of electricity in the Global South, and I echo his claims 1) that anthropology is important for electricity because electricity infrastructure is a social and political manifestation, and 2) that electricity infrastructure is an imperative anthropological subject because it is consequential to society's future existence [68].

Throughout this project, I have been deeply invested in developing an empirically grounded understanding of electricity infrastructure vis-à-vis development. Yet, through my research activities, I have grappled with producing work that is socially embedded. As an electricity development scholar, I am implicated in the same contradictions and presumptions I have observed and now hope to shed light upon. Knowledge of the social is ultimately "knowledge from particular points of view" [173]. Thus, as a converted social scientist and critical theorist, my work does not seek "objective" truth, it strives for a historically and culturally contingent interpretation of the world (c.f. Burawoy [28]). With these epistemological considerations, I turn to my research methods.

The empirical work I employ is both qualitative and quantitative in nature. For my primary case study in Unguja, Tanzania I have conducted semi-structured interviews across the island, as well as taken electricity measurements from various locations. The interviews were guided by the constant comparison method [57, 155], by which the theory and interview data work together iteratively, and hypothesis generation follows. In addition, I conducted voltage sampling across dozens of locations and employed a long-term study of voltage measurements across two distribution feeders in Unguja in order to capture the temporal and spatial variation. Lastly, I conducted 150 surveys, gathering data from almost all customers connected to the measured distribution feeders. I use my fluency in Swahili and familiarity with electricity systems to conduct fieldwork and document analysis.

Discourse analysis allows me to make sense of the plethora of documents on and related to contemporary electrification projects produced in the last 15 years or so, including: government policy documents and reports; transcripts of parliamentary sessions; donor reports and memos; NGO reports; scholarly works in development and economic journals; newspaper and magazine articles; and other unpublished materials. I focus on analyzing the structure of the discourses produced by specific actors and institutions, namely how the repetition of similar arguments, statements, concepts, and categories translate knowledge into power [49].

1.4 Theoretical Approaches: Electricity, Development, and Power

I take on two overarching theoretical movements. The first is using power and governmentality as a lens to examine development practices and outcomes. The second is understanding

development and environment through political economy.

Power and Governmentality

Historian Marc Bloch, quoting early 20th century French poet Paul Valéry, cites the "'the conquest of the earth' by electricity, as an example of one of those 'notable phenomena' which [a historian] neglects, despite the fact that they have 'more meaning and greater possibilities of shaping our immediate future than all the political events combined'" [24]. Through Valéry, Bloch prefigures my desire to frame electricity as a powerful tool of social change, and also to draw it from its isolation in technical disciplines and into those of humanities. To this end, I engage with Michel Foucault's concepts of power and governmentality, which allows for a deeper reflection on the consequences of electricity development. In fact, Foucault himself considered electricity as an important development in the exercise of political power [50].

Governmentality, a termed coined by Foucault, refers to a particular post-Enlightenment relationship between the state, population, and the exercise of power. Formally, it is "the ensemble formed by institutions, procedures, analysis and reflections, calculations, and tactics that allow for this very specific, albeit very complex, power that has the population as its target, political economy as it major form of knowledge, and apparatuses of security as its essential technological instrument" [50, p. 108]. This ensemble found its coherence not in punishment but in the making of a subject through disciplinary techniques [50, 1]. In the context of contemporary development, the electric meter (prepaid or postpaid) is one example of a disciplinary technique through which political power is exercised [170, 106, 86].

The works of James Ferguson [44], James Scott [146], Timothy Mitchell [116], Antina von Schnitzler [170], and Tania Li [104] explore how numerous development projects have been planned, implemented, and justified through the deployment of modernizing discourses and technical expertise, and how they have produced powerful depoliticizing effects and other unintended consequences. While Scott, in Seeing Like a State, brings to light the role of the "all-seeing" state in shaping development insidiously through the powers of science [146], Mitchell, in Rule of Experts, takes a more nuanced approach. For Mitchell, techno-politics "is a particular form of manufacturing, a certain way of organizing the amalgam of the human and nonhuman, things and ideas so that the human, the intellectual, the realm of intentions and ideas seem to come first and to control and organize the nonhuman" [116, p. 43, emphasis added]. My work is rooted in this vision of techno-politics: electricity development has its own technical and institutional coherence, but where the human begins or ends is unclear.

Development, the Environment, and Electricity

What is development? At a broad level I engage with the political economy of development, situating electricity development within the history of capitalist development and nation-building. Importantly, I consider development as relations, particularly between nation-states, individuals, corporations, NGOs, and experts. Such framing contrasts with develop-

ment as a stage-like historical process, e.g. Rostow's stages of growth [139], or Marx and Engels's stages of capitalist development [110]. Working across an international divide, development scholars argue that development serves to produce highly unequal exchanges [51, 8, 12]. Similarly, critical geographers use the concept of "uneven development" [150, 75] to highlight the spatial and temporal variation in national economic development.

The role of the state is a central theme in development debates. Classical economic perspectives frame the market and the state as distinct and often argue for the freedom of the former from the latter [76]. Modern economic discourse pits governments against the market, especially with respect to public-related services. John Maynard Keynes, a key figure in modern economic thought [116], countered the notion that free markets necessarily maximize welfare. He believed that state intervention was critical in certain circumstances, such as investment in high-risk capital [96]. The Chicago school of economics opposed government interventions due to perceived bureaucratic pitfalls [166], which markets avoid by being more efficient. Both sides of the debate, however, assume markets to be "disembedded" from governments [132]. That is, they are able to follow their own distinct logic. However, recent scholarship has sided against this market/state division, for rational actions are inherently embedded in systems of social relations [66]. This claim is supported by "free-markets" needing constant governmental and social support [44], and by scholars of Adam Smith himself, who argue Smith never divided the spheres of economics and politics [140]. Drawing on this latter framework, I support the position that electricity development, with its contemporary emphasis on market-driven reforms, is still working in and through distinct socio-political relations.

Two overarching literatures can help us make sense of the relationship between electricity infrastructure and societal relations. The first is the Science and Technology Study (STS) literature on LTS, following the terminology of Hughes [80]. This work contextualizes technical systems as both socially constructed as well as shaping the society within which they are embedded. STS eschews the analysis of technologies as "basic science" in action, instead seeing technological inventions such as energy systems as intrinsically ethical, environmental, and political [163]. Following Star [151], an STS framing recasts infrastructure as a relational phenomenon, not simply a "system of substrates" existing invisibly (p 380). How infrastructure is seen, felt, and understood is thus contingent on a set of relations and processes: it becomes visible when it breaks down, e.g. when bridges are washed away or when the power goes out [26], or when its becomes a barrier, e.g. a wheelchair is forced to traverse stairs [151].

The STS framework has been embraced by the political economy of development literature on technology, infrastructure, and development, which is the second strand of literature that I lean on. Large infrastructure systems have been characterized in postcolonial political economy as contributing to state control (cf. Scott [146]) but also to state legitimacy [10] – at first of the colonial state in Asia and Africa but subsequently of the postcolonial state, which retained many practices of the past. I draw on this literature to better understand the spread of electricity services in SSA. The critical studies of technology within postcolonial development have argued that the application of large and visible technologies in the develop-

ing world served as a marker not only of economic development but also moral advancement [169]; prominent scholars have argued that colonized countries could be ranked and evaluated in part by the status of their scientific thought and technological progress (Adas 1989). Thus authors have argued that the build-out of large, impressive infrastructures was central to the "civilizing mission" of colonialism (cf. Fisher-Tiné and Mann [45]). This perspective has, in turn, been critiqued as being too Western-centric or colonizer-centric, though we can understand the history of technology in previously colonized countries as perhaps colonizer-centric because it strives to understand the work that these technologies accomplished for the colonial mission.

Finally, I explore the environment through the lens of political ecology. I give importance to the productive nature of material forces in shaping relationships [109], diving deep into the material world of electric currents, wires, poles, transformers, kilowatt-hours, and voltages, together with the diverse set of agents that electricity infrastructure carries. These users, operators, engineers, and policy makers embody conditions that are socially and materially produced and reproduced. Many scholars use political ecology to analyze the production of urban spaces (e.g. Swyngedouw [157]; Loftus [105]). Silver [148], for instance, uses political ecology to understand the "disrupted" electricity infrastructure in Accra, Ghana, and the ways "historical infrastructural governance, greenhouse gas emissions, flows of international capital, water and drought in northern Ghana, as well as urban sprawl, slum urbanism and rising energy demand in the city" affect the uneven development of electrification [148, p. 984]. Still, agency within electricity governance has largely been stripped of the physical system in much of the literature, including in Silver's work. "Load shedding" appears as the prime form of nefarious interruption in poor SSA communities [148, 17], and even this is inconsistent with the ways in which electricity infrastructure manipulation can take place. Inadvertently, this scholarship confuses social agency and material forces, and thus legitimizes through its obfuscation certain forms of political involvement. My work does not shy away from the intricacies of the physical system, and the opportunities they pose for being manipulated, transformed, and shaped.

1.5 Context: Political Economy of Grid Development

The abundant electric grid is the story of its political economy. Centralized electricity grid systems, known today as Legacy Grids, proliferated throughout North America and Western Europe in the early 19th century. Through a coordinated back-and-forth of enormous supply and wartime demand for electricity, these systems provided ample electricity. Newfound electricity generation sources, such as dams in the Pacific Northwest, ostensibly provided limitless electricity [174]. Industrial facilities, such as aluminum plants, necessary for military manufacturing and operations, demanded enormous amounts of electricity.

Electric utilities benefited from this political and economic configuration, and thus were sensitive to its changes. Lulls in peacetime profits drove utilities to promote other sources of demand [81]. These sources included energy-intensive fluorescent light bulbs [22] and diverse

household electrical appliances [79]. And still, electric utilities in these regions struggled to stave off threats of bankruptcy.

In The Organic Machine, historian Richard White details the financial vulnerability of peacetime electricity provision. In the late 1960s, the Bonneville Power Administration (BPA) in the Pacific Northwest feared supply constraints from low water conditions on the heavily-dammed Columbia River, and they gambled on capital-intensive large nuclear facilities [174]. However, in the 1980s, when demand for electricity did not materialize from existing users after billions of dollars had been invested, the BPA "once again needed aluminum smelters as customers for revenues to pay off its spiraling debt" [174, p. 80].

The history of these grids informs modern consumption (c.f. [14]). Today, after decades of energy efficient measures have been implemented and electric appliances saturate homes, electric utilities once again search for demand to prop up revenues. The goal of "electrify everything" supports this demand, especially through the promotion of electric vehicles [136]). In the context of "modern energy for all," this search for new users and uses motivates the interest in "developing" or "emerging" markets.

"Modern energy for all," with its initiatives to increase electricity access in poor communities, is global in nature, yet sub-Saharan Africa has been a primary target for much of these efforts. Electricity grids in SSA are state-run or state-regulated and are considered unreliable and insufficient. Although electricity access reports and economic scholarship often link state involvement and poor service quality, examples of state-run or regulated systems that provide ample and reliable electricity exist (contemporary South Korea is one example). Still, technical and economic discourse on electrification maintains that in order to provide reliable services and expand coverage, countries must prioritize privatization and support certain technical interventions to reduce economic inefficiencies.

Scholarship on the SSA's electricity sector links its privatization (or at least private-public reforms) superficially to successful electrification. Under a broad discussion of Ghana's electric power sector, the World Bank lauds the country's favourable 84 percent electrification rate (the second highest in SSA) before emphasizing that it was "one of the first countries in sub-Saharan Africa to unbundle its power sector to attract private investment" [179]. Gnansounou et al. [58] are unequivocal as to why Ivory Coast has a reliable electric grid: "A complete privatization of state-owned electricity companies is recommended to all countries of the [West African] sub-region. This solution succeeded first in Ivory Coast; however, it has been so far unsuccessful in several other countries" [58, p. 2, my emphasis]. They conclude, "many countries are backward in the progress due to lack of private investments required for renovation and development of energy infrastructures" (ibid.). However, academic research about the impact of privatization on reliability and expansion is sparse and one of the few academic studies on the topic, Plane [131], suggests a more complicated picture. He concludes that those looking to generalize vis-à-vis Ivory Coast's story should be wary of the preexisting institutional and economic conditions found in the country, which most certainly aided its present day "success."

Similarly, Plane's warning may be applied to Ghana: what pre-existing conditions existed in, and in what ways were they connected to, Ghana's successful electric grid? Hidden

in Ghana's 84 percent electrification rate lies the story of an enormous generation capacity provided by one of the largest dams in SSA, the Akosombo Dam, and ample bauxite to support a strong, electricity-consuming aluminum industry. British colonial rule first identified the potential for an aluminum industry in the region, which was later realized by the independent Ghanaian state through donor support. Today, technical scholarship is dismissive of this state-led, economic precondition. Instead of concentrating on Ghana's comparatively high electrification rate, it focuses on Ghana's managerial inefficiencies to explain why all of Ghana is not electrified. In contrast, Tanzania's utilities remained British-run well into independence and privatization was realized significantly more than in Ghana, yet the electrification rate is only about 34 percent. Furthermore, the little success Tanzania's grid has achieved arose from state-led development through widespread cross-subsidies and lifeline tariffs, but "these redistributive policies were reinterpreted as uneconomic under marginal cost reforms" [55, p 62]. All this suggests that the relationship between privatization and successful electrification is more complex than is presently acknowledged.

Nevertheless, at least a dozen SSA states have taken steps towards privatization. They continue to subsidize electricity [6, 97], but with an increasing emphasis on the user as the locus of cost-recovery. Two regularly targeted sources of inefficiency are theft and nonpayment (often grouped together); the user allegedly connects to the grid illegally, tampers with their meter, or fails to pay their electricity bills. Current strategies to counter nonpayment are geared towards the domestic customer, such as the expansion of metering and consumption-based payment [93, 164]. While the conventional postpaid electric meters remain the norm (where customers pay after using), prepaid services are growing in SSA, in part because utilities and policy makers see their instant disconnection feature as a more reliable route to cost-recovery [20].

1.6 Ethnographic Case Study: Unguja, Tanzania

Unguja, Tanzania, the largest island in the Zanzibar archipelago, is illustrative of contemporary electricity development throughout much of SSA: although foreign entities have invested heavily in the Unguja electric grid, it creates daily challenges for its relatively poor Zanzibari users. With massive colonial wealth, Unguja became one of the first places in SSA to gain electricity [172]. Home to the Sultan of Oman in 1800s, Unguja was a key port for the East-African slave and ivory trade. A century later, and financed in part by the Norwegian Development Agency and managed by the Zanzibar Electricity Corporation (ZECO), the grid reaches more than 50 percent of Unguja households [86]), but many consider its service to be unreliable and of poor quality [73].

Furthermore, ZECO serves a population whose median, self-reported, monthly income ranges from 50 USD to 200 USD [162]. However, residents pay roughly 13 cents per kilowatt hour, a price comparable to that in many high-income countries. Though the vast majority of scholarship concerning reliability focuses on impacts to business and industry, the material conditions created by Ungula's grid determine the pattern and pace of everyday life. Poor

power quality, with frequent outages, mandates rearranging day-to-day activities.

Mismanagement by utilities and consumer theft are perceived to be the primary failures of electricity provision in SSA, though very little evidence exists about either. Various reports show ZECO owing TANESCO (Tanzania Electric Supply Company, the mainland Tanzania utility) between 20 and 30 million USD, although the exact number is in dispute [84, 111]. As of 2017, ZECO purchased electricity from TANESCO at a higher rate than what they charged customers [118]. As such, an increasing debt, combined with mismanaged tariff structures and subsidized electricity rates, has created a constant budget deficit for the island's only utility company. ZECO also faced accusations of providing its management team and higher-level staff with free electricity and generous gifts, and of wrongly charging large commercial customers thousands of dollars not detailed in their electricity bills [161, 111].

Despite the company's internal mismanagement, ZECO customers have emerged as the primary focal point for reforms. World Bank reports state unequivocally that full cost-recovery is critical to maintain a functioning utility, and therefore a functioning grid. Under the guise of cost-recovery, so-called thieves and non-payers are targets of policies and technology intervention. Citing the systemic problem of unpaid electricity bills as a major concern, ZECO is in the process of shifting payment regimes from a completely postpaid metering system to a prepaid one. The prepaid meter forces consumers to pay prior to using electricity to ensure full cost-recovery. However, according to ZECO sources, government institutions owe the utility 12.8 million USD, whereas small businesses and domestic consumers owe 4.5 million USD [111, 188]. With a substantial portion of the utility's deficit coming from government institutions and larger users, the prepaid option has its limits unless all – or at least most – users switch to a prepaid meter. In the meantime, the ordinary citizen, who is responsible for the smaller proportion of ZECO's debt, carries the financial and discursive responsibility for removing this debt, and is, at least implicitly, responsible for the financial sustainability of the electric utility.

The electricity system in Unguja is unexceptional. Throughout SSA, states are challenged with providing a costly service deemed necessary for modern living, and with balancing between recovering costs and serving their largely vulnerable populations. And throughout the region, utility providers focus on theft and nonpayment, shifting the responsibility to maintain a sustainable electricity grid to individual users. Without scrutiny of the assumption that electricity is good, equitable, and abundant, and without understanding the real history of electricity, the development community risks misplacing blame for failing electricity infrastructure on end users and thus risks imposing misguided interventions.

1.7 Project Overview

My dissertation uses electricity development in sub-Saharan Africa (SSA) as a window into three related aspects of contemporary electricity development: the evolution and fragmentation of authority and responsibility in the governance of electricity provision; the production

of everyday life in constrained electricity systems; and implications of using abundant grids as benchmarks. I combine a historical comparative analysis and ethnographic and case study work with surveys, interviews, and two years of voltage measurements based on my monitoring of the electric grid to answer the following questions:

What patterns of responsibility and authority have emerged with the rise of prepaid electric meters? This question draws largely from ethnography work in Unguja, Tanzania. Through years of exploratory interviews, and exploratory hypothesis generating, I work to understand how prepaid meters have reshaped relationships in Unguja's electricity landscape. I use a case-study approach and discourse analysis to investigate the patterns of responsibility and authority emerging with changing electricity regimes. Specifically, I look for where the burden of responsibility is being placed, and where authority and power are exercised.

What everyday life do constrained grids produce? In light of constrained grids, is the mission of "modern energy for all" attainable and desirable? These last questions take their point of departure from the assessment that grids in SSA are constrained, and these constrained systems act as vehicles for a particular way of life. While scholars have stressed the need to incorporate dimensions of quality in reliability studies, few scholars equate poor quality with voltage variability and access. Thus, I scrutinize the claim that reliability is integral to electricity access. I do so by using a unique combination of interviews, surveys, power systems analysis, and social critical theory to examine the politics of every day by assessing the consequences of being connected to an unreliable grid.

In investigating the assumptions of abundance, equity, and goodness, my research finds that they work in and through one another to reinforce environmental inequities and injustices along the grid. First, by prioritizing abundance without scrutinizing the conditions that produced it (i.e. the creation of excessive electricity generation capacity, a heavy focus on industrial customers, and broader ecosystem of electricity consumers), I find that practitioners and policy makers are misplacing blame on low-income households for the failures of SSA infrastructure. Second, in communities like Unguja, misplaced blame for failing systems jeopardizes equitable access. Specifically, I find that poor households, like those in Unguja, shoulder the responsibility for maintaining and sustaining constrained electricity systems, even if industries and government institutions (the largest consumers in the electricity ecosystem) are more indebted and physically burden the system more. Lastly, I argue that under an initiative that centers around the individual household for cost-recovery, constrained systems will continue to spread. In Unguja, a constrained connection adds chores and costs associated with uncertain access, broken appliances, and high electricity bills. Within this context, electricity access risks compounding inequalities and undermining the goodness electricity is purported to provide.

The intellectual merit of this research lies in the critical examination of a contemporary electricity development and understanding the ways in which it re-configures social relations. Specifically, it advances multi-disciplinary knowledge on how and why various assumptions within electricity infrastructure dominate the discourse and affect policy and technology; how authority and governance on the ground become fragmented amidst prevailing changes in

electricity governance; and how communities connected to unreliable grids – as environmental subjects directly affected by the constrained grid – renegotiate their everyday life.

In ***chapter two***,[2] I explore equity as it relates to "modern energy for all," and specifically the rise of prepaid meters as the technical solutions to theft and mismanagement in SSA. While the Zanzibar Electricity Company is in the process of switching from a postpaid system to the prepaid system in order to manage their debt problems, about 50 percent of residents still use postpaid meters. I use this as my case study, to compare the two systems together, and focus on the island of Unguja. I draw on 14 months of fieldwork and document analysis, including the government's online database of government meetings and utility-related articles from local and regional newspapers.

I find that the rise in the prepaid meter represents a shift away from a provider- and user-centered relationship to a more overtly techno-human one, with new roles for Unguja residents. For the state-owned utility, a less visible, seemingly distant relationship with its customers emerged. Importantly, I find that although governmental and non-governmental institutions are, on average, more indebted to electric utilities, utilities and foreign donors (such as the World Bank and IMF) push prepaid meters more aggressively on residential users. Thus the responsibility for "unsuccessful" grids is discursively and actively falling on residential users, but also the vulnerabilities these constrained systems induce.

Chapter three explores the material conditions of constrained electricity systems and the implications for "modern energy for all," the internationally-supported initiative to connect populations to electricity services. The spread of electric grids has become a primary strategy for meeting sustainable development goals, especially in sub-Saharan Africa. However, when electricity is supplied by a capacity-constrained grid to a resource-constrained population, the service quality can vary both spatially and temporally. This chapter investigates the quality of electricity services based on a case study of Unguja, Tanzania. Using (i) open ended interviews, (ii) detailed electricity-systems monitoring, and (iii) household surveys, I show how voltage quality varies significantly, even within highly localized settings. Fluctuations result in dim lights at best and power outages and broken appliances at worst, denying many Unguja residents the expected benefits of access to modern energy. By combining an extensive understanding of the physical system together with interviews and surveys, this work presents a unique mapping of voltage quality in a system that is financially and physically constrained and highlights the consequences of poor-quality service for poor

[2]Readers will find the use of "we" in chapters 2 and 3. These chapters are versions of published papers with collaborators from multiple disciplines. I believe the use of anything other than "we" would have been dishonest without changing the chapters entirely. Thus, although a bit jarring, I left it written as such. I imagine some readers might think collaborative research is somehow "less work" for individuals involved. As the lead on both, whatever "less work" resulted from having multiple contributors was made up by the constant effort needed to mediate between them, facilitate edits, incorporate different ideas and perspectives, and doing all that is required to lead a project to its final stage. I was involved in every aspect of these pieces, from creating the research project itself, to doing all of the requisite fieldwork and data analysis, making the graphs and tables, and interpreting the findings and writing them up. All collaborators have thus given me permission to use these publications for my dissertation and readers will find them credited in the beginning of each chapter.

users.

Finally, in ***chapter four***, I investigate what it means to be connected to constrained electricity systems for everyday life in Unguja. I take an ethnographic approach, and use semi-structured, open-ended interviews, conducted between 2014 and 2016 in Unguja. I show that a connection to a constrained infrastructure versus an infrastructure built on abundance has implications for the way users and the infrastructure interact, and in how precarity is perpetuated and normalized. Under Unguja's constrained grid, the handling of uncertainty, variability, and insecurities falls on the residents—to unplug, to purchase stabilizers, to readjust daily activities to the conditions of the grid. While residents express some frustration, this expression is also coupled with a normalized sense of uncertainty and contingencies by residents and policy makers. As one energy consultant said "residents can cope" with poor quality access. Nevertheless, where energy access promises to free up time by mechanizing traditional tasks and to increase workday hours by providing additional light, this work shows that a constrained connection fragments a continuum of everyday life.

* * *

By working within and across disciplinary boundaries, I show the distinct social and material relations and responsibilities offered in and through these constraining conditions. An evaluation of the assumptions embedded within electricity build-out and an understanding of the real history of electricity are critical to determining responsibility for "unsuccessful" electricity infrastructure. The possibility of misplaced blame sets policy-makers up to implement inappropriate and even harmful interventions and solutions in the name of environmentalism and poverty reduction. This work has moral and ethical implications for the future of "modern energy for all," where the subject is the low-income household: the benefits imagined for them, but so too the burdens and responsibilities.

Chapter 2

The Prepaid Meter: Rights, relationships, and reification in Unguja

2.1 Introduction

Sustainable Development Goal 7 (or SDG 7) – the United Nations initiative to "ensure access to affordable, reliable, sustainable and modern energy for all" – rests on the link between access to clean energy services and improved living conditions for the poor [168].[1] Researchers on energy policy and advocates for the rural and urban poor have strongly argued that access to affordable and clean energy is essential for the alleviation of deep poverty and poor health in the developing world (e.g. Smith, 2002; Sagar, 2005). In the quest to decrease the reliance on polluting fuels for cooking, heating, and lighting in low-income communities, SDG 7, with the light bulb and power button as its symbols, in effect promotes the universal right to basic electricity services. While such a right has no formal recognition, universal electricity access is now widely seen as a proxy for social and economic rights [167].

Many non-governmental initiatives, as well as foreign aid and foreign direct investment efforts, are devoted to electrification projects. Prominent examples include calls for universal access to electricity by the United Kingdom and the United States through their Power for All (UK) and Power Africa (USA) campaigns. Sub-Saharan African government initiatives include Ghana's Universal Electrification Plan and Ethiopia's Universal Electricity Access Program; their efforts reinforce the recognition of electricity as a necessity in the modern world.[2] These initiatives include the construction of electricity infrastructure, the distribution of new technologies within existing systems, and the reconfiguration of utility practices through new policies.

Providing electricity services, especially universal basic services, entails significant capital, operations and maintenance, and ongoing delivery costs. Since these costs must be paid for,

[1] A version of this chapter was published in World Development in 2018. The co-author, Isha Ray, has given permission to have this work included in this dissertation

[2] See: https://www.gov.uk/government/news/britain-and-us-unite-to-power-up-africa. Also [19], and [95] for programs in Ghana and Ethiopia, respectively.

it is either up to the taxpayers (i.e. through direct or indirect taxes that go into government revenues) or up to the service users (i.e. through various fees) to pay for them [74, p 15]. Even if the upfront or operational costs are financed by an international loan or by private investment capital, eventually these sources must be repaid either via taxation or via user fees. Who pays - taxpayers in general or specific consumers - ultimately dictates the nature and extent of electricity access for individual households. Access for all demands cost-recovery to maintain and extend services, and affordability to be 'for all', at the same time. Therefore, a tension surrounds the discourse on the implementation of SDG 7. Human rights goals and their advocates are more concerned with who has, and who does not have, access to basic electricity services than with who pays for what. Cost-recovery goals and their advocates are also concerned with access, but argue that it is neither practical nor productive to expect costs to be borne entirely, or even mainly, by the state. The terms of commodification - or, who pays, how they pay and how much they pay - are thus intimately connected to the ways in which either goal can be met. Two questions follow: Should the taxpayer or the user pay, and in what proportions? Second, if the user pays, should payments be made before the service is made available or after? This paper is concerned with the implications of the second question.

Radical changes in payment regimes are taking place in Sub-Saharan Africa (SSA). Partly a reaction to perceived flaws within utilities' cost-recovery techniques (discussed below), utilities in SSA are moving away from a postpaid electricity system – one in which users pay after a period of use – to a prepaid system in which users must pay prior to use. A report by the NorthEast Group, a smart technology and infrastructure consulting firm based in Washington, DC, projects a 234% growth in the market value of prepaid electricity meters for SSA by 2034 [123]. This report has helped to redefine the status quo in metering technologies, with academics, other consulting firms, and online news outlets citing it heavily.[3] The Zanzibar Electricity Corporation (ZECO) is one such SSA utility switching over to prepaid services as the preferred mode for their customers.

The roles and responsibilities of user and provider are different in each payment regime. The change in metering technology disconnects users instantaneously when their "units" run down; unlike the postpaid system, prepaid meters in SSA do not need a meter reader or utility employee to measure consumption or disconnect users. Thus, as we shall argue, prepaid systems are set to alter the human engagements previously established through the traditional postpaid system, i.e., the relationships between user and provider, the meter, and the electricity service itself.

Recognizing that the mode of payment for electricity is but one entry point into the social relations embedded in technologies, we explore the following questions:

(i) Given that prepaid and postpaid meters both commodify electricity services, what difference do the terms of commodification (i.e. how and when users pay) make to low-income communities and to the utility?

[3]See, for example: [16, 85, 143]

(ii) If access to electricity embodies a set of implicit and explicit social relations what difference do the terms of commodification make to these relationships?

We use the findings from these questions to discuss our final, broader question:

(iii) Affordable and clean energy *for all* is the seventh Sustainable Development Goal. How do the terms of commodification affect whether, and how, SDG 7 may be met?

This is the first paper (that we are aware of) to critically compare the perspectives of both postpaid and prepaid users in a single region transitioning from one metering regime to the other. As prepaid becomes the preferred meter in SSA, we examine the changing relationships embedded within each payment system. In line with previous research, we find that the prepaid meter disciplines users to use no more than what they can afford [78, 89], [4] and has the support of the utility in large part because it reduces its nonpayment problem [130] We find that many customers prefer the prepaid meter; it controls them (as they see it) through its automatic disconnection mechanism, but this control helps them to control their finances [54, p. 417], [16]. The change from postpaid to prepaid therefore relieves vulnerable consumers of debt, but that relief comes with the fear of being left in the dark. The smallest consumers in our study, in fact, preferred postpaid meters. We also find that the prepaid meter tends to become reified in these low-income communities, often being conflated with the service provider in common discourse, and implicitly providing the utility with a certain distance from customer dissatisfaction. Electricity problems that were once blamed on a "cheating" ZECO staff, or on an incompetent meter reader, now tend to be attributed to the *mita mpya* (the new meter) itself.

When a basic level of electricity access is considered akin to a right, is one of a handful of globally agreed-upon development goals, and offers the possibility of improved living conditions for the poor, we must critically assess the nature of the security(ies) on offer when prepaid metering replaces postpaid. In our case study of Unguja, Tanzania (where ZECO operates), we argue that financial insecurity for many hitherto postpaid consumers has been replaced by insecurity of access to the electricity service itself. For most of these consumers, financial insecurity was the greater stressor; nevertheless, with automatic disconnection but without a low-priced (or free) lifeline entitlement, the lowest-income households are at risk of falling through the cracks of SDG 7. The utility is more secure with the prepaid meter, because customers can no longer rack up unpaid bills. However, we find that the discourse of controlling debt and using "only what you can afford", with which prepaid meters are promoted, applies largely to the residential and micro-business sectors. Many (though not all) government entities that are in heavy debt to the utility and large private sector customers continue on the postpaid system, while the public face of ZECO's debt remains the lay citizen.

[4] Similar point made by von Schnitzler [170].

2.2 The electric meter and the terms of commodification

The terms of commodification for basic public services determine the universal or otherwise nature of access to, and use of, such services. The debate on who should pay for electricity has brought to the forefront the difficulties of commodifying it without excluding individuals from the benefits it brings.

Whether payment should come from general revenues or individual users, and how the costs should be divided, is a debate that centers around fairness, affordability, and efficiency.[5] In principle, state-subsidized electricity provides affordable access for the poor, yet for the poor to benefit from subsidized electricity rates, they need a connection. Not everyone can afford the often steep upfront cost of a connection [176]. Furthermore, because electricity consumption and income are not always correlated, consumption-based subsidies – a common strategy – often benefit medium- and high-income households rather than those most in need [13, 65]. Thus, opponents of state subsidies see them as economically inefficient and socially inequitable, and advocate for their reduction. At least a dozen SSA states have taken steps towards this end; many continue to subsidize [6, 97], but with an increasing emphasis on the user as the locus of cost-recovery. This partial shift from a general cost-recovery strategy towards a user-centric one is taking place in several service sectors beyond electricity.

Where taxpayer-subsidized electricity rates remain important, providers look to make optimal use of existing resources by minimizing service inefficiencies [**Eberhard2008**, 171]. One regularly targeted source of inefficiency is nonpayment; the user fails to pay his or her electricity bills, resulting in what utilities call "arrears" if they remain unpaid. Nonpayment of utility bills is common in SSA and beyond. Bill payment losses to a utility are measured by calculating total cash collected in each year as a proportion of total revenue billed in the same year. A 2016 World Bank report claims that bill payment losses, which include nonpayment, range from roughly two percent in nine SSA countries to above 25 percent in six [164].[6]

The literature suggests two causes of nonpayment: users' inability to pay [42, 100], and a "culture" of nonpayment. Two separate reports published by the World Bank suggest that the lack of a strong payment culture leads to customers refusing to pay their bills [27, p 100], [137, p 112]. Prominent economists have argued that "no one wants to pay for it" when electricity is seen as a right and not a private good (e.g. The Economist, February 27 [160]). Alternatively, critical theorists argue that nonpayment is a form of "the quiet encroachment of the ordinary" [18], or a counter politics of citizens simply unable to afford the essentials of modern urban life. Some researchers suggest that the incapacity to pay is much more the norm than the (alleged) payment-resistant "culture" among Africa's urban poor (e.g. Plancq-Tournadre, [130]). Other reports reveal that a large portion of unpaid bills belong to government institutions and larger, non-residential users [171, 164]. Discussions

[5] See [175, 41]

[6] Utilities also deal with other technical and non-technical losses, such as electricity theft through illegal connections, meter tampering, and breakages (see Winther, 2012). Therefore, bill payment losses are only part of a utility's loss portfolio.

around nonpayment and efficiency, however, usually revolve around the average residential user. Current strategies to counter nonpayment are also geared towards the domestic customer, such as the expansion of metering and consumption-based payment [**keelsonlow**, 164]. While postpaid meters remain the norm, prepaid services are growing in SSA in part because utilities and policy makers see their instant disconnection feature as a more reliable route to cost-recovery [20].

In the postpaid system payment is made after a period of consumption, for example, at the end of a monthly cycle. While users consume units (kilowatt-hour or kWh), the postpaid meter measures and displays accumulated consumption. Generally, a meter reader reads the number displayed by the meter and subtracts the current reading from the previous one to tally consumption for a billing period.[7] To pay, customers can go online, or mail a check, or travel to billing offices, depending on how a specific system is set up. Failure to pay results in arrears (i.e., accumulated unpaid bills), and the disciplining of nonpayment occurs through fines and the possibility of eventual disconnection. This is an unreliable system from the utility's perspective, because the postpaid system is a credit risk, enabling nonpayment. Reports also suggest that, for utilities, postpaid systems encourage "poor payment discipline" as they allow for collusion between the meter reader and the user [71, p 4], [97]. Prepaid meters are designed to block the flow of electricity unless payments have been made; they were initially introduced into South African townships as a reliable system for a population that was considered unreliable and not creditworthy [89]. In prepaid systems, users pay prior to consuming. If electricity costs 10 cents per kWh, a customer purchasing 5 USD worth of kWh would receive approximately 100 kWh; kWh can be bought from utility offices, or third-party vendors, and in some regions, remote payment is possible with cellphones. The meter counts down as the units are consumed. Once 100 kWh are used up it disconnects the supply, automatically cutting off users who have not "topped up" (i.e., pre-purchased additional kWh).

Baptista [16] nicely summarizes the range of critiques of prepaid systems, which have been called a proxy for neoliberalism, a disciplining technique over citizens, and a political tool. Linking broad neoliberal policies with prepaid metering, [141] sees these meters as a form of responsibilization, or, the supplanting of traditionally government responsibilities by new demands made on the individual (also Heusden [78], Schnitzler [145]). Critics argue that by promoting this shift under the guise of universal access, and crediting the new regime for enabling usage within one's means, the utility tasks the meter with a dual agenda. On the one hand, it relieves the utility's debt concerns, while on the other hand it implies that universal access is achievable as long as users can afford it. Earlier work on the UK experience also critiqued prepaid meters for "effectively [hiding] or [disguising] the issue of low levels of access" [64, p 299]. Following this critique, [68] sees the use of prepaid meters

[7]The use of a meter reader is common in SSA, while in other parts of the world postpaid systems do not always require them; reading can be done remotely, and at varying intervals, depending on their technical capacity. These specific meters are called "smart meters" or automatic meter reading devices. In addition to reading usage, many also offer two-way or one-way communication between the provider and user, real-time electricity use data or even emissions information.

by the poor as a paradoxical situation in which access exists but electricity may not. Many scholars view these meters as tools of control over low-income users, arguing that the change from the risk of debt to that of disconnection jeopardizes the rights of poor people [78], or that when money is unavailable residents may go "stretches of time without lights or clean water" [115, p 203]. Survey results from Ghana show that low-income prepaid users worry about disconnections [135, 117]; survey results from Zambia and South Africa also indicate that constant rationing may lead to the increased use of charcoal and wood for cooking [108], and to "self-disconnection" by cutting out "superfluous" tasks such as heating and ironing [130, p 22].

Prepaid meters clearly have advantages, critiques notwithstanding. From the perspective of consumers, the prepaid meter offers increased control over consumption, payment and debt. After surveying prepaid customers in SSA, four studies conclude that the meter provides users with budgeting support, reductions in consumption through (self)-rationing, and increased awareness of consumption [158, 117, 108, 112]. Baptista [16] finds prepaid users in Maputo to be largely satisfied with their control over budgeting and consumption; given the tenuous economics of the urban margin, she credits the prepaid meter with enabling residents to pursue at least some modern comforts. Differentiated services, and differentiated modes of paying for services, contrary to traditional arguments against "splintering" the urban population, may actually narrow rather than accentuate access gaps by providing new opportunities for access ([88], cf Graham and Marvin, [64]).

From the perspective of the utility, the prepaid meter reduces inefficiencies through streamlining bill delivery as well as bill collection, and by rendering continued nonpayment obsolete. It serves as a "technological upgrade" by virtue of replacing the old technology. Although prepaid meters cost more than postpaid upfront, they reduce non-revenue usage and the cost of bill collection services [126, 98]. The World Bank has approved funding for prepaid installations in several Sub-Saharan African countries, citing both these aspects as the benefits of their loans [181, 180, 182, 183]. Furthermore, utilities faced with electricity theft worry that users can tamper more easily with postpaid meters [158, 119] and so welcome their replacement.[8]

Metered consumption, whether prepaid or postpaid, commodifies electricity services. The implicit assumption behind both sides of the payment-timing debate is that the switch from one mode of commodification (postpaid) to the other (prepaid) changes the relationships between the consumer, the provider, and the electricity service itself. To understand the intersection of commodification and its attendant social relationships, we turn to the concept of reification.

Reification (literally, "thingification") is said to occur when individuals engage with others through the process of commodifying goods and services [109]. Social relationships between people subsequently become expressed by and through the commodified object. Lukács

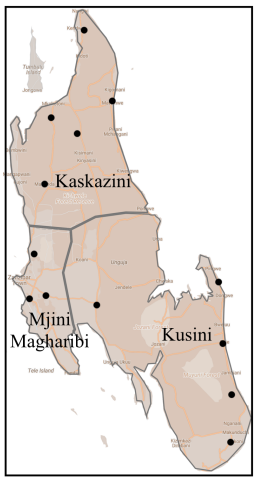
[8]Various modes of electricity theft are common in our study site of Unguja [177]. Replacing postpaid with prepaid technology has yet to produce significant reductions in theft, however: one study actually found an increase [38].

argued that reification makes the commodity or object seem to be actively determining actions and relations [107]; when this phenomenon becomes normalized, market exchange is no longer seen as one particular form of interaction among many, but as a "*natural* form of social interaction" [91, p 237, emphasis added]. The increasing presence of technologies embedded within the commodification process heightens this condition [43]. Technological mediations further fragment human-to-human engagements, and can themselves become reified such that "man-produced things" appear to become "independent of man ... and govern his life" [129, p 411].

In *The Reification and Dictatorship of the Water Meter*, Loftus shows that water services in Durban, South Africa are commodified through mechanized monitoring and measuring by the water meter; in this process the meter appears to gain people-like qualities [106]. Loftus argues that the water meter attains a governing power over everyday rhythms, imposing itself on prior habits. By analogy, the electric meter can also impose itself on prior patterns of electricity use. Our research in Unguja finds that the prepaid electricity meter, in particular, becomes reified, at least in cash-constrained settings within SSA. Postpaid technology visibly relies on human intermediaries to measure and disconnect, setting it apart from prepaid technology, which consolidates the tasks of measuring and disconnecting within the device itself. This new mode of access isolates the user from the utility by taking away the key intermediary, the meter reader. It takes away the visits to the utility offices to pay bills and the visits from the utility for bill delivery and collection. The technology itself seems to take on a governing role in the flow of electricity; the reliability of the prepaid regime rests on the technology, with its surveillance and disciplining mechanism, whereby "[disciplinary power] is exercised through its invisibility" [48, p 187]. Drawing on the concept of reification, we show that these changes bring about a technologically-induced reshaping of how customers view the utility, the meter, and the electricity service itself.

In this study, we compare the prepaid and postpaid meter through the experiences of low- to middle-income consumers in Unguja, Tanzania. We make explicit the nature of those changes through a comparison of the perceptions and practices of prepaid and postpaid users; we examine who controls what and how, who lends and who borrows from whom, and how the user-provider relationship is "seen" in both regimes. Thus far, the literature on modes of electricity (or water) commodification and the social relations embedded therein, has analyzed these changes mainly through a postpaid lens, without comparing these in detail to the impacts of paying through the postpaid meter. The postpaid regime has served as the benchmark for (paid) urban electricity because the majority of the world uses it, and prepaid therefore represents a change from what seems normal. Such normalization has allowed the deficiencies of postpaid meters relative to prepaid meters (and of prepaid relative to postpaid), from the users' perspectives, to be underemphasized in studies of electricity access. Our research breaks from this tradition by drawing equally on experiences from postpaid and prepaid users in Unguja, where we look not only at what the meter does but also at how it is seen.

(a) Mainland Tanzanian and the Zanzibar archipelago [59].



(b) The island of Unguja with sampling sites and regional divides. Zanzibar Town is located in the southwest region, or "Mjini Magharibi".

Figure 2.1: The Republic of Tanzania

2.3 Electricity services and payment in Unguja, Tanzania

Unguja, Tanzania (Figure 2.1) is a semi-autonomous island off the coast of East Africa. According to a 2014 wage report, the median wage in Zanzibar[9] was 125 USD per month (1 USD = 1,600 TSh in 2013); those who were self-employed earned on average 50 USD a month, and those on contracts earned 200 USD [162]). ZECO, the only electricity provider in Unguja, provides services to approximately 53 percent of households,[10] with per capita consumption in 2009 at approximately 106 kWh per year [61]. Given this yearly consumption, an average five-person household would consume roughly 1.5 kWh per day, which is enough to power a few hours of TV, energy efficient lightbulbs for a small home, and a fan.

Citing the systemic problem of unpaid electricity bills as a major concern, ZECO is in the process of shifting payment regimes from a completely postpaid metering system to a prepaid one. The first prepaid meters were installed in early 2000 through a World Bank loan [180]. As of 2014, domestic and small commercial customers using postpaid meters made up ∼23% of all electricity used, while similarly-situated prepaid customers used ∼40%

[9]Zanzibar is an archipelago, which consists of two main islands - Unguja, the largest, and Pemba.

[10]This estimate is from our own calculations, based on Tanzania's National Bureau of Statistics April 2014 Report on the Basic Demographic and Socio-Economic Profile of Zanzibar, Tables 12.9 and 12.10 (https://tanzania.go.tz/egov_uploads/documents/TANZANIA_ZANZIBAR_SOCIO_ECONOMIC_PROFILE_sw.pdf). Previous work from specific sites in Unguja has reported lower coverage rates (e.g. [177]).

[125, p 67].

The postpaid and prepaid systems in Unguja resemble the generalized structure laid out in the previous section. Postpaid customers typically travel to the main billing office in Stone Town (otherwise known as Zanzibar Town) to pay their bills, although ZECO staff visit villages far from the main office on a monthly basis to collect billed payments. Residents can choose to pay using this method, or travel the hour or so (one way) to Stone Town. For prepaid meters, the main office provides vouchers for kWh purchased, but many smaller stores around the island do the same - allowing customers to purchase top-up kWh closer to their homes.[11] Disconnections with postpaid meters are supposed to occur when a user has arrears; there is no clear cutoff threshold, however, and many customers continue using electricity despite small arrears.

Poor tariff structure and mismanagement allegedly plague the Zanzibari electric utility, contributing substantially to its debt crisis. Overall, ZECO is said to owe TANESCO (the mainland Tanzanian utility) between 20 and 30 million USD, although the exact number is in dispute [**zanzinews2015baraza**, 84]. A mixture of subsidized electricity rates and lack of state funding creates a constant budget deficit. As of 2017, ZECO purchased electricity from TANESCO at a higher rate than what they charged customers [118]. Government institution arrears, running into the millions, greatly exacerbate the debt crisis. According to ZECO sources, government institutions owe it $\sim$12.8 million USD, whereas small businesses and domestic consumers owe 4.5 million USD [**zanzinews2015baraza**, 189]. ZECO also faced accusations of providing their management team and higher-level staff with free electricity and generous gifts, and of wrongly charging large commercial customer thousands of dollars not detailed in their electricity bills (The Guardian, January, 2013; **zanzinews2015baraza**, **zanzinews2015baraza**).

The electricity system in Unguja is not singular. Similar problems, similar patterns, and similar policy shifts from postpaid to prepaid metering are occurring across SSA. Throughout the region, states are challenged with providing a service that is deemed necessary for modern living, and with maintaining the fine balance between recovering the cost of that service and serving their largely vulnerable populations. And throughout the region, the metering changes aimed at greater cost-recovery are directed mainly at small users rather than at large public or private institutions.

2.4 Data and Methods

We incorporated three components to analyze the differences between the payment systems for the users and the utility, and for the social relationships that underpin electricity services: semi-structured interviews with ZECO customers, key informant interviews with ZECO staff, and content analysis of available documents. Fieldwork took place over the course of three extended visits by the first author, from 2014 to 2016.

[11] There are plans underway to have mobile device capabilities so customers can purchase top-ups via their cellphones. See: http://www.thecitizen.co.tz/News/Business/1840414-3306120-2mrstdz/index.html

The first trip focused on preliminary observations of the electricity network and day-to-day workings of Zanzibari life. Daily observations helped in identifying areas with postpaid and prepaid meters, the location of the main utility office and regional payment centers, and the modes of transportation accessible to regions around the island. We established a working relationship with ZECO, and conducted our first twenty interviews with its customers. Interviews began with basic questions concerning monthly electricity consumption, and the billing and payment process. Many people spontaneously offered up their personal grievances or notes of satisfaction, through which the ways in which the utility and electricity were being seen and discussed started to emerge. We encouraged people to discuss their views on postpaid meters if they had switched to prepaid, or on prepaid if they had postpaid; these conversations revealed their preferred mode of access and why. To gain baseline perspectives on both systems we also interviewed three small business owners, chosen at random amongst those that sold electricity appliances and lighting fixtures. These interviews revealed user experiences as relayed by customers to the shopkeepers, and further informed our own user interviews.

The semi-structured interviews established the importance of embedded relationships within Unguja's electricity system. While responding to questions about their monthly consumption and payments, users often discussed (without prompting) their interactions with, and reflections on, the meter and meter reader. We noted these and asked follow-up questions where possible. While responding to service provision questions, such as their level of satisfaction with their electricity connection, many respondents also divulged their views of ZECO as a service provider.

Over 2015 and 2016 we conducted an extensive set of interviews, incorporating insights from the initial 20, on the everyday practices of those using postpaid and prepaid meters, and on how their users saw ZECO and the access to electricity that ZECO provided. We broadly followed the constant comparison method [57, 154], a method in which the final interview dataset and the theoretical understanding of a social phenomenon are iteratively determined.[12] This resulted in 45 new semi-structured interviews of electricity users. Our interview protocol allowed for themes to emerge naturally with each new conversation, adding content and direction to the subsequent ones. This process continued until saturation, i.e., when user responses started to produce little variation. Over the course of seven months a total of 65 interviews were conducted, of which 51 were complete enough to be included in this study.

Participants chosen for the semi-structured interviews had different job statuses, included women and men, were postpaid and prepaid users, spanned age groups and family sizes, and were geographically dispersed (Figure 2.1b). Unguja's urban center is Stone Town (Figure 1b), and the majority of the population lives within its broader periphery (the Mjini

[12][57] originated the method of constant comparison, whereby a few initial concepts and processes are identified in the setting of the study; data collection is based on the researcher's initial understanding of the phenomenon of interest; the data are systematically coded around the initial concepts [154]; and the next round of data collection is purposive and draws on emergent concepts from the previous rounds. Thus the full scope of data collection cannot be laid out in advance, nor can pre-held hypotheses be tested.

Magharibi region). Stone Town also contains the main ZECO billing center. We approached many individuals while walking through different neighborhoods, chosen through observations as being poor or non-poor, urban or non-urban (noted by differences in habitation density and distance from markets), and having predominantly postpaid or prepaid meters (these were easily detected from the street). Neighborhoods were differentiated as poor or non-poor according to the quality of roads and household building materials (concrete, thatch, coral rock, wood, or tin). We relied on snowball sampling for difficult-to-access neighborhoods and for people in categories that remained underrepresented through our primary approach. Most participants welcomed the chance to be interviewed. The first author conducted all interviews in Swahili; the interviews lasted between 45 and 120 minutes.

Between trips and after the final field visit, we undertook content analysis of documents relevant to the broader socio-economic background of Unguja. We analyzed data from a 2012 population and housing census by the National Bureau of Statistics (NBS), Tanzania, and a 2013 study by the Oxford Poverty and Human Development Initiative (OPHI) [120, 127]. OPHI establishes incidence of poverty using the following indicators: health, education, living standards ("cooking with fuel, sanitation, cooking water source, access to electricity, type of floor and ownership of assets") [120]. These statistics show that ∼51 percent of rural Zanzibaris lived below the poverty line in 2012, compared to 36 percent in urban areas; rural areas were also at greater distances from key facilities such as schools, markets, and hospitals [120, p 12].

To understand the perspective of the service provider, we relied first on document analysis, including the Zanzibari government's online database on government meetings and ZECO-related articles from local and regional newspapers. These helped us to gather information on current policies and their evolution, and informed our open-ended key informant interviews with utility staff members. The interviews lasted between one and three hours each. Our questions focused on cost-recovery efforts by the utility, the major hurdles facing their efforts to decrease debt, ZECO's general budget, the status of the prepaid meter rollout and prepaid meters' popularity among ZECO customers. Following these interviews, we returned to relevant newspaper articles, and expanded our analysis to transcripts of government proceedings involving ZECO (which we translated from Swahili). We conducted follow-up interviews with utility staff, incorporating the knowledge from our field observations and our document analyses. These interviews took place in ZECO offices.

2.5 Results

We begin by summarizing the socio-economic characteristics of our research sample. Households without access to electricity and likely to be living in extreme poverty were not included in this study.[13] Clear-cut income levels are difficult to capture in Unguja. Many households

[13]Our work and its findings, therefore, may not apply to the very poorest citizens of Unguja; it can justifiably be argued that the rights of those with no electricity connections are even more unmet than those with connections but only tenuous access to the service. We thank an anonymous reviewer for bringing our

have transient members, who, depending on age, may or may not contribute to household income. Some heads-of-household have multiple wives and multiple homes, further complicating total income assessments. Furthermore, it became clear early in the interviewing stage that participants were uncomfortable explicitly addressing income; they were perhaps simply unsure, as common jobs found on the island and among our sample include self-employed, short-term contract, agriculture, and tourism jobs. These vary seasonally and create variable cash flows from month to month.

Table 2.1: Regional and Sample Characteristics

	Unguja		Sample	
Region	Households (#)	Poverty Incidence (%)	Interviews (#)	Bottom Tier (%)
Kaskazini	39,884	58	18	35
Kusini	24,612	20	9	33
Mjini Magharibi	126,314	35	23	5

Regional and Sample Characteristics. Number of households and poverty incidence in Kaskazini (North), Kusini (South) and Mjini Magharibi (Town/West) regions of Unguja (shown in Figure 2.1b). The right columns represent the sample population.

We divided our sample study into bottom, middle, and top socio-economic tiers in order to present a nuanced representation of Unguja's socio-economic levels. To this end, we placed households in each tier after cross-checking the OPHI data and the 2014 wage report [162] with our own observations of household assets, as well as answers to questions regarding our respondents' job status and size of family. Table A.1 shows a summary of socio-economic characteristics per region). Reported income is unreliable in Zanzibar (as described above), so the following offers a glimpse of a top-tier household in this economy: at least one individual working a consistent job (not self-employed or owner of a small household business), on average fewer than four children, at least one piece of immovable furniture in the home (e.g. table or couch), one motorized vehicle, and an overall structurally sound home (see Appendix A Figures A.1 and A.2 for photos of typical low-, middle-, and top-tier homes).

For this study, the electrical devices owned by the households were only a partial marker of socio-economic status (Figure 3.7). Furthermore, we found no clear pattern between

attention to this.

appliances owned and reported monthly electricity consumption. The Y-axis in Figure 3.7 represents devices owned by participants; these are vertically stacked in increasing order of their typical electricity consumption, or load size (see Table A.1). Although there is an increase in the diversity of appliances from bottom- to top-tier households, many appliances across all groups were found broken or apparently unused (e.g. clothes were piled on top of electric ovens, or fridges were unplugged, or appliances were tucked away in dark corners). In the rest of this section, we lay out our findings on the terms of commodification for electricity services and the human relationships underlying these terms. We contrast the postpaid and prepaid systems and highlight both user and provider perspectives.

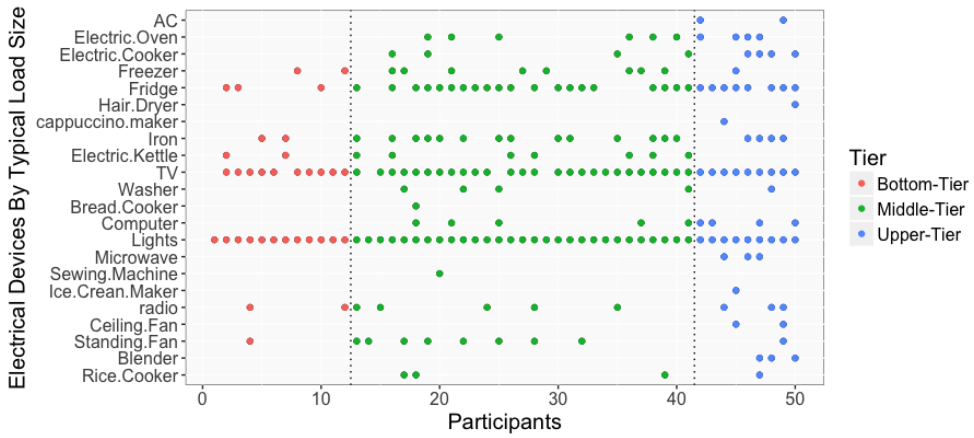


Figure 2.2: The Y-axis represents devices owned by participants, vertically stacked in increasing order of their typical electricity consumption. The X-axis represents participants, grouped in bottom-, middle-, and upper- tiers (in that order), divided by dashed lines.

The terms of commodification and the user: debt versus the dark

The process by which users pay differs in postpaid and prepaid systems, not only in the timing but also in the mechanics. For some in Unguja, the postpaid system was complicated, making prepaid systems desirable by virtue of their simplicity. The postpaid billing system required all payments to be taken to the main offices in Stone Town. Those far from the ZECO office could make their payment to ZECO staff during monthly collection visits, but suspicion and anxiety resulted if their payments were somehow unaccounted for through the process (similarly noted in Winther, 2012). In Nungwi, a village in the far north region, for instance, one interviewee summarized his sole complaint with the postpaid system:

> [W]e are thankful [to ZECO] but in the payment procedures, it's important for them to place a good procedure – it's necessary for them to just come a couple

> of days or one day before, before they come to cut electricity off [from] someone that hasn't paid, ... Like today, you go to pay, you get your receipt, you walk to your house... [you] return to your home and there isn't any electricity – it's an interruption. This does upset me. It is the number one annoyance I have. Number one.

Many with postpaid meters made the (often) long trip to ZECO headquarters just to avoid such complications. ZECO streamlines the payment process for prepaid meters by placing more locations around the island to purchase top-ups.

The main difference between the user experience with prepaid and postpaid meters was the perceived control over electricity usage and hence over money. In principle, of course, the user can control his / her use of electricity regardless of the timing of payment: what changes with shifting the timing is the consequences of those choices, and the perception of control over his / her choices. Our respondents reported a significant overall preference for prepaid meters, especially at the middle-tier. Figure 2.3 shows the number of responses favoring prepaid versus postpaid at the bottom-, middle-, and top-tiers, separated by whether the user had had personal experience with only one or both types of meters. We note that no experience with a meter does not imply no knowledge. Participants regularly interacted with a neighbor's meter reader, helped a family member top-off their prepaid meter, or visited a family member with a different meter.

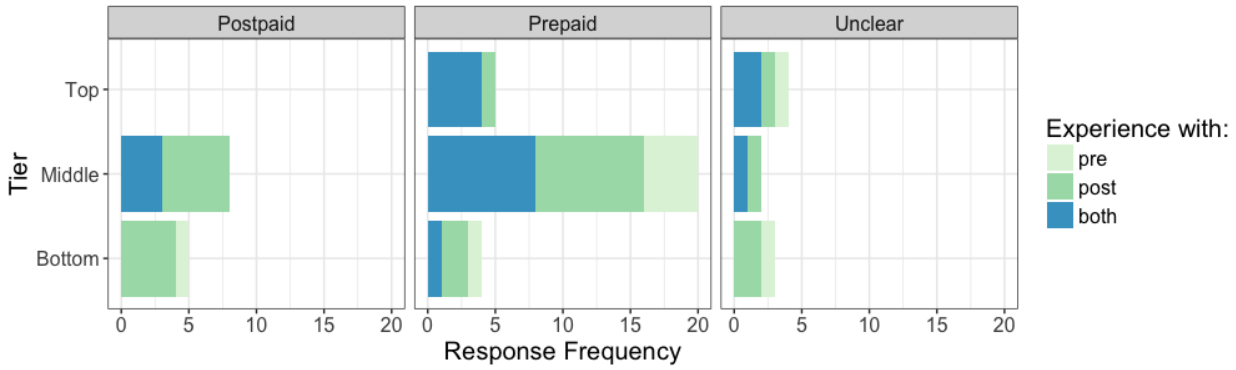


Figure 2.3: Figure 3 shows the number of responses favoring prepaid versus postpaid per tier, and separated by whether the user had had personal experience with only one or both types of meters.

The users in our study, whether they preferred prepaid, postpaid, or were neutral, displayed a complex web of preferences, fears and insecurities. The postpaid meter left customers in debt to the utility at the end of the billing period. Users in our study whose debt felt manageable expressed anxiety over disconnections with prepaid meters. In general, the minority with a preference for postpaid meters felt that, even if money was tight, the

postpaid system was lenient enough to allow a minimum necessary level of consumption: "debt you [can] pay off little by little, but while you are paying you can keep using it." Users who feared that their debt would accumulate thought that prepaid meters managed their consumption, and allowed them to use only what [they] could afford. In effect, they preferred the risk of a blackout to the risk of increasing arrears. Socio-economic tiers among our respondents were not unambiguous predictors for who preferred post- to pre-, rather, the lowest levels of consumption were associated with a clear preference for postpaid. Those who lived with no more than a fan, some lights and a TV highly valued the security of continued services. Figure 4 shows the relationship between the interviewee's reported monthly consumption and his / her preferred metering device (those with unclear or no preference are not listed). The data points correspond to respondents, while the horizontal lines indicate the median consumption for each preference group.

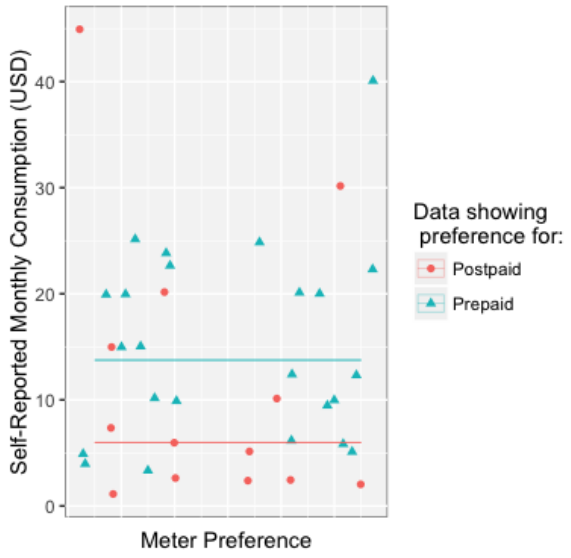


Figure 2.4: The Y-axis represents interviewee's reported monthly consumption and the X-axis his / her preferred metering device. Data points correspond to respondents, and horizontal lines indicate the median consumption for each preference group (the top line corresponds to prepaid preference, and the bottom line to postpaid).

The terms of commodification and the utility: secure payments, lower costs

For the service provider, there were clear advantages to using prepaid meters. The shift in the timing of payment committed their customers to paying prior to consumption, so a revenue stream was created irrespective of short-term provision. This shift offered ZECO the possibility of reducing their debt burden to the mainland utility, both by reducing user

nonpayment and by eliminating the costly task of following up on arrears. In proceedings from a 2009 meeting held by the Zanzibar Assembly, a ZECO representative stated:

> [Honorable] Speaker, [ZECO] continues with its plan to monitor the sale of electricity debt for the purposes of reducing arrears from customers. This program has greatly helped to reduce ZECO's debt from Tsh 6.3 billion to Tsh 5.5 billion during the 2008/2009 fiscal year ... The intention of [ZECO] is to continue with the "Pay your bill" campaign due to its success in ensuring that debt continues reducing [190, p 31].

The representative follows this summary with the status of current work concerning debt and the "Pay Your Bill" campaign: the installation of 20,000 prepaid meters was underway, only a few thousand remained [122, p 9]. In a similar vein, in its 2009 report on Zanzibar-related electrification projects (support for prepaid meters included), the Nordic Consulting Group[14] claimed that "... between [sic] April to September 2008 ZECO reports a loss of energy of 26% in Unguja (energy purchased compared to energy sold). This is still high but lower than in previous years, when the loss of energy to a large extent also included energy delivered but not paid for due to failures in billing and meter reading routines" [122, p 9]. With donors such as the World Bank providing much of the capital for prepaid installations [181, 180], ZECO staff told us that they were waiting to replace more postpaid meters as soon as the next tranche of money was made available.

Relationships embedded within the modes of payment

Each mode of payment was underpinned by a set of implicit and explicit relationships between the user and the provider, and the user and the service itself. Table 2.2 shows how these roles change when prepaid meters replace postpaid ones. The metering device has three functions: monitoring use and determining payment, disconnection and restoration, and setting the terms of credit. The prepaid regime signals a more visible role for the electric meter itself for the first two functions, effectively placing the utility at a distance from its own measurement device (and from the user). For the third function, prepaid systems move the upfront payment for electricity from ZECO to the user, therefore the customer (in effect) lends money to the utility before receiving any services. These changing roles and associated relationships are mediated by how the work of the meter is seen in each payment regime.

Relationship between user and the provider

By streamlining electricity payment, prepaid systems remove the consistent monthly engagement of the user with the meter reader. The meter reader's monthly visits were a source of tension for some and a source of information for others. An older male respondent noted that his long relationship with the meter reader assured him that his electricity bill would

[14] See http://www.ncg.dk/

	Actors	
Function	**Postpaid-**	**Prepaid-**
Monitoring Use & Determining Payment	1. ZECO 2. Meter Reader 3. User 4. Meter	1. ZECO 2. Meter 3. User
Disconnection and Restoration	1. ZECO 2. User	1. Meter 2. User
Lender	1. ZECO	1. User

Table 2.2: Actors in Postpaid and Prepaid Regimes

not be miscalculated. As a postpaid customer, he said, "right now, if he doesn't come I have his number... I was [also] taught how to read what number [the meter is at]." Others, however, complained that the meter readers failed to provide adequate information, making prepaid meters more attractive: "I like [prepaid] better than the ring meters because, with those, we do not understand [what's happening] and the utility doesn't explain to us what's going on."

The meter reader's connection to the utility reflected poorly on the utility when users suspected that the reading of the meter was improper. Several participants expressed distrust of ZECO staff and its meter readers (also Winther, 2012); they frequently used the words "cheated" and "corrupt" while discussing their postpaid electricity bills: "the people at ZECO, they cheat you." They noted large discrepancies between their perceived consumption and the monthly bill for that consumption. For some, this "cheating" drove their preference for prepaid: "Given no problems with corruption, I would prefer the old meters because I used less electricity."

Discrepancies between the meter readings and perceived consumption were also common among prepaid users. In such cases, however, there appeared to be no meter reader and its associated "cheating" utility to blame; the discrepancy was routinely attributed to the meter itself: "It runs too fast. The *mita ya zamani* (old meter) gave more units." Or:

"[prepaid meters], they run out fast; [prepaid] uses more power." A top-tier user explained her frustrations regarding prepaid meters: "The other day I went to the utility's offices, and I told them I think there is something wrong with my [prepaid meter] because most of the time I'm at work and my husband most of the time is at work, so why is it running out so fast?"

Relationship between user and the service itself

We found substantial evidence that consumers self-regulated their electricity consumption in the prepaid regime. When substitutes were available and when the meter was "running too fast", prepaid users switched from electrical appliances to traditional devices that used biomass-based fuels. This was clearly a response to scarcity and the need to avoid sudden disconnection. For example, bread-making is frequently done in electrical ovens and several respondents baked breads to sell. When money was tight and units on prepaid meters were low, some turned (back) to charcoal or wood stoves: "Many times [the units run out], therefore we use a wooden cooker." Similarly, rice cookers and water boilers were used differently with postpaid and prepaid electricity services. Unprompted, one interviewee explained that she stopped using her electric rice cooker once she switched to prepaid meters. After noticing that her units ran down faster when using a rice cooker, she said, she returned to older methods for cooking. For lighting, kerosene or candles were used as alternatives: "[W]hen you don't have money you can [just] use candles."

2.6 Discussion and Conclusion

Our work offers a critical look at new and old forms of electricity commodification in Sub-Saharan Africa. Using a case-study approach, we investigated the ongoing switch from postpaid to prepaid meters in Unguja, Tanzania. We explicitly compared perceptions and preferences of prepaid *and* postpaid meter users in this transitory regime. By viewing electricity access and use not only as a service, but also as a set of relations between the user and the provider, and between the user and his / her electricity, we show how the change in payment-timing and metering technology reshapes implicit relations among the three. In particular, the utility has set the stage for a less visible, seemingly distant relationship with its customers (see Graham and Marvin [64]): one that shields it from customer dissatisfaction through the reification of the prepaid meter. We argue that the shift away from a provider- and user-centered relationship to a more overtly techno-human one presents individuals with a new set of vulnerabilities as well as opportunities. The shift may not be fully compatible with a commitment to the right to basic electricity.

Prepaid meters have been widely critiqued as tools of control and disconnection over lay citizens; our study shows that they do seem to exert control over everyday patterns of cooking and lighting, forcing the user to watch her limited units and her limited cash. Nevertheless, our interviews and content analyses of primary documents revealed broad support for the

prepaid meter by users and the provider, both of whom expressed significant concerns over debt. The willingness by domestic users to relinquish control to the meter is a testament to their financial insecurity. In welcoming (and reifying) the prepaid meter with its automated disciplining mechanism, users project stronger fears of being in debt than being without their lights, their TVs, and their cookers. The lurking fear of disconnection is real, but it is often preferable to the "corrupt" utility staff, the onerous payment method for the *mita ya zamani*, and unmanageable arrears. The term "reification" is used as a critique in the literatures on technology and society (e.g. Casey [31]; Levidow [103]; Loftus [106]). Our study suggests that this critique must be tempered in the context of a utility whose customers distrust it, and an economy in which consumers would rather revert to candles and charcoal than to rack up debt.

This finding casts some doubt on the alleged "culture of nonpayment" in SSA. A 2008 World Bank study on modern services in SSA found that all income quintiles had significant nonpayment incidences, and concluded that nonpayment within "the richest quintiles suggests problems of payment culture alongside any affordability issues" [15, p 30] (also cited in [46, p. 91], and [137, p. 113]).[15] However, our participants, many of whom expressed frustrations with their inability to meet monthly payments, nonetheless endorsed a meter that enables constant surveillance and, in effect, makes nonpayment obsolete. This choice cannot stem from a "culture" of nonpayment: most respondents *preferred* a pay-by-usage regime.

Among the lowest-consuming users, however, postpaid meters brought security from disconnection; this led to a preference for the old technology. They could pay off their debt gradually while continuing to use essential electricity services. Prepaid meters are promoted by pointing out that low-income users can consume in accordance with their cash flow: they can top up their kWh in small quantities. The other side of that argument, though, is that postpaid meters allow users to pay off their debt in small quantities. For users whose needs amounted to lighting, and the occasional TV or fan, the insecurity of small debts to be paid off in small bits can be much less worrying than the insecurity of sudden disconnection. Postpaid meters offer such users an important safety net, allowing usage even when they cannot afford it.

From the utility's perspective, the cost of serving low-income communities has proven to be financially overwhelming. In March 2017, President Magufuli of Tanzania ordered the Zanzibari government to start paying off their debt to TANESCO or face an island-wide disconnection (The Daily Nation, March 20, 2017 [159]). As ZECO continues to subsidize electricity rates with users already struggling to pay their bills, it is left in the challenging position of increasing revenue through other means. Through calls to eliminate nonpayment, the prepaid meter has become a favored tool. With a substantial portion of their debt coming from government institutions and larger users, however, the prepaid option has its

[15] For this the study the quintile range falls between households making "$50 per month in the lowest quintile to no more than $400 per month in the highest income quintile, except in middle-income countries, where the richest quintile has between $600 and $1,200 per month" [15, p viii]. Tanzania is a low- rather than middle-income country, therefore the lower range is more relevant.

limits unless all – or at least most – users switch to a prepaid system. In the meantime, the ordinary citizen, who is responsible for the smaller portion of ZECO's debt, carries the financial and discursive responsibility for removing this debt.

We have argued that at the core of the electricity service system is a set of embedded relationships and perceptions, and that the advent of the prepaid meter has brought about a technologically-induced reshaping of these relationships. With the shadow of mismanagement hovering over Unguja's electricity sector, the reification of the prepaid meter shields ZECO from consumer ire. Rather than ZECO taking the blame for inadequate levels of service, it is now the mita mpya that runs too fast. By adopting prepaid meters, the utility severs the relationship between the meter reader and the user, making the *mita mpya* the de facto "face" of ZECO. By severing this relationship, the utility inadvertently removes an avenue of information for low-income or elderly users. The lack of a human interface at the user end is the other side of the efficiency of metering and billing argument with which prepaid meters are promoted. Finally, the mode of commodification determines the creditor/debtor relationship between utility and user: the utility offers services prior to payment in a postpaid regime, and thus acts as a creditor to users. This relationship flips with a prepaid regime, in which the users lend money (interest-free) to the utility, and get paid back as they consume the service. As lenders, users are doubly vulnerable when the quality of the service is low, which is the case in many SSA regions including Zanzibar [37]; it is quite possible to pay in advance for electricity and then not get it when needed if ZECO is supply constrained for whatever reason (also [68]). A recent World Bank report asserts that utilities should "consider pros and cons of mandating prepaid meters if service quality is poor," as a prepaid regime might lead to customers paying "in advance for electricity not delivered when needed" [97, p 30]. As our research shows, however, the World Bank and others continue to promote prepaid meters across SSA.

Looming over the laudable language and earnest intentions of SDG 7 is the reality of self-regulation and self-rationing among prepaid meter users. While access to electricity is promoted for its potential to reduce polluting fuels in the home, and their associated negative health impacts [149, 53], our findings suggest that prepaid meters may incentivize the return to these fuels when cash is not available or units run out. Periodically returning to cooking with biomass is particularly damaging to the health of household cooks, who tend to be women. Prepaid users also self-regulate their consumption to avoid being in the dark; the frequency with which this phrase came up in our research indicates that it reflects genuine anxiety even among those who preferred prepaid to postpaid systems. Sudden and automatic disconnection arguably puts SDG 7 at risk of not being met for the most vulnerable, and thus at risk of not being met for all.

Postpaid meter regimes may have similar outcomes if users remain perpetually disconnected by the utility or strictly budget their own consumption. Yet by claiming that prepaid meters benefit poor customers by removing the risks of disconnection – because of vigilant self-regulation, and allowing access only when disposable cash is available – many reports ignore the realities of prepaid payment regimes. We do not argue that cost recovery in the electricity sector is unimportant for a utility or for a state. We do find that the prepaid

regime can deny service at the point-of-use even when the user is unable to pay. If access to electricity in Africa becomes more and more contingent on payment prior to use, with no guaranteed lifeline consumption, this is not compatible with a commitment to universal basic access. As one of our participants succinctly put it: "With prepaid [meters] – no money, no connection."

Chapter 3

Power Quality and Modern Energy for All

3.1 Introduction

Safe lighting, a working TV, and a charged cell phone have arguably become basic needs in today's world.[1] Increasing access to electricity services, therefore, has become a primary strategy for meeting international development goals. Non-governmental initiatives, as well as foreign aid and foreign direct investment efforts, are devoted to increasing electricity access to improve human conditions in poor communities UN2018report. The most prominent expression of these efforts is Sustainable Development Goal 7 (SDG 7) – the United Nations' initiative to "ensure access to affordable, reliable, sustainable and modern energy for all" UN2018report. The implicit assumption that electricity services will promote better lives if provisions are adequate and equitable underpins SDG 7 as a key sustainable development goal.

In sub-Saharan Africa (SSA), with international donors and local governments investing in grid expansion, approximately 190 million people gained access to electricity between 2000 and 2014 [185]. Recent work has focused on SSA's renewable energy potential, attempting to displace carbon-intensive generation sources in an affordable manner (see e.g. [144, 186]). Expanding grid access, regardless of energy source, entails costly transmission and distribution infrastructure [138]. These services and systems in SSA are routinely described as inadequate [92], unreliable [47], and disrupted [148]. In this paper, we refer to such electrical systems as 'constrained,' because the distribution systems are capacity-constrained, and also serve financially constrained populations. Power outages, brown outages, and voltage fluctuations are commonplace in these systems, which continue to expand in Africa and Asia. In contrast, in high-income countries, customers typically face fewer than five hours

[1] A version of this chapter was published in the Proceedings of the National Academy of Sciences in 2019. Co-auhotrs include Noah Klugman, Belinda Grunfeld, Catherine Wolfram, Duncan Callaway, and Isha Ray. All authors have provided permission for me to include this work in the dissertation.

of service interruption per year [11, 36]. For the majority of households across the US and Western Europe, power outages and voltage variability are not a concern; the grid supplies near-constant and unvarying electricity.

This research provides an empirical description of the nature of electricity access under a constrained grid in the SSA community of Unguja, Tanzania. We focus on electricity quality, in particular on voltage along the distribution system. Electricity access scholarship has moved beyond discussing connections [10, 3] and has begun to incorporate dimensions of customer experience, such as reliability and voltage quality (e.g. the multi-tier framework of the World Bank and the International Energy Agency [10]). However, little existing work illuminates the extent to which power quality shapes de facto access in SSA households; most research to date on power quality focuses on businesses and industry [9, 4]. Aklin et al. (2016), one of the few studies to engage with power quality at the household level, relies only on household perceptions to capture incidences of low voltage [3]. Lee et al. (2017) concludes unequivocally that "we currently have almost no data on even the most basic patterns of outages in developing countries" [101, p. 6].

We measure household-level power quality in Unguja by monitoring voltage fluctuations on the local grid. We highlight its implications for adequacy and equity within the service area. Our work reveals the everyday unreliability of electricity in, and the consequences of unreliable services for, income-constrained households. As capacity-constrained grid systems such as the one in Unguja expand, this research speaks to how energy and development scholars characterize and analyze the quest for "modern energy for all."

The Unguja grid reaches more than 50 percent of households [62]. Financed in part by the Norwegian Development Agency and managed by the Zanzibar Electricity Corporation (ZECO), grid services in Unguja are described as unreliable [73]. ZECO serves a population whose (self-reported) monthly income in 2013 ranged from 50 USD to 200 USD [162]. However, residents pay roughly 13 cents per kilowatt hour, a rate comparable to several high-income countries, rendering many uses of electricity a luxury.

Unguja is not exceptional. Reports across SSA reveal an electricity landscape characterized by poor quality and costly service [164, 184]. Poor voltage quality is characterized by drops, sags, fluctuations, and spikes. Electric utilities set an allowable range for voltage fluctuations, commonly plus or minus five percent of the nominal voltage (+/- 5% of 120V), as in the US, or plus or minus ten percent (+/- 10% of 220V), as in Unguja. In high-income countries, distribution feeders have instruments such as capacitor banks to maintain the desired voltage along the transmission lines. Limiting voltage fluctuations is important because, although common household appliances can function with small deviations outside of the allowed range, they can be damaged by larger deviations [39]. For example, motors found in fridges, blenders, or electric pumps can overheat with voltage fluctuations, thus decreasing their lifespan [25]. Similarly, the incandescent light bulbs commonly used in SSA, and also in Unguja, break faster with voltage fluctuations. CFL and LED light bulbs are supposed to function the same regardless of voltage, but the light intensity for CFLs can vary with voltage [147], and the cheaply-made versions that many financially-constrained people buy are susceptible to breakage under large voltage fluctuations [90].

Our research offers a unique mapping of voltage quality in Unguja, and provides insights into the consequences of poor quality electricity services on household welfare. To our knowledge, this is one of the first studies to measure, and to document the lived experience of, the near-daily and unpredictable voltage fluctuations in the region. Our mixed-methods approach included 62 open-ended interviews, 151 household surveys, and electric power systems monitoring over the course of two years - using monitoring devices designed by Power Standards Lab [133] and devices that our team designed and built specifically for the study. In the following sections we lay out our results and discuss the implications of our research for the pursuit of "modern energy for all."

3.2 Methods

We took a mixed-methods approach, using 62 open-ended interviews, 151 household surveys, and two years of voltage measurements to monitor the electric grid. Our open-ended interviews followed the grounded-theory approach [56], where interviews build upon themselves iteratively, allowing for themes to emerge and be continually coded until saturation. The majority were household interviews, with some small businesses included. Our sampling strategy was purposive (i.e. a non-random sample broadly selected for the characteristics of the population and the objectives of our study). It was designed to elicit a range of experiences and perceptions, and to ensure broad socio-economic and locational representation. Our structured surveys, included almost all the customers on the grid in our study locations. The surveys were distinct from, but informed by, the 62 interviews (see Appendix B for more information).

Because technical terms commonly used when discussing electricity are unfamiliar to everyday users, and because perceptions and experiences vary, survey terminology required "shopping around" to ensure broad understanding. With fluency in Swahili and power-systems terminology, the first author cataloged power quality conditions with their associated experiences. Thus, voltage fluctuations were identified as *umeme unapanda na unashuka*, which literally means "electricity goes up and down." Such language readily captures light bulbs growing brighter or dimmer and fans sounding louder or softer. We completed 151 structured surveys in Sites A and B (see Figure 3.3 and Appendix table B.1 through B.6). The surveys were informed by the initial 62 interviews, and, after piloting, were administered by three local enumerators. They were completed over the course of two weeks.

Voltage measurements were taken using two high-resolution power quality monitors (PQubes) at 11 homes in 5 distinct regions of Unguja during 2016 (see Figure 3.2). The PQubes were provided by Power Systems Laboratory [133]. We then used 14 devices built specifically for the study to measure voltage in Sites A and B between December 2017 and June 2018. The devices were placed strategically throughout the two sites. PQubes were installed at the transformers for sites A and B, and were used to verify base voltage profiles for each site.

Voltage data are available without locational identifiers through Dataverse under the project title "Power Quality and Modern Energy for All." Raw survey data are available on

request; when the authors are finished with their ongoing analyses, these will be posted on Dataverse. The study protocol was reviewed and approved by the Institutional Review Board of University of California, Berkeley: Protocol ID: 2014-04-6289. We obtained consent from every interviewee and survey respondent after sharing information about (i) the scope of the research, (ii) the voluntary nature of their willingness (or refusal) to participate, and (iii) the absence of any cost, benefit or potential risk of participation (or refusal to participate) in the study.

3.3 Results

Power Quality Variation in Unguja

Figure 3.1 shows the study locations, marked as small circles and squares, with the lines representing the centralized grid. Our interviews with ZECO customers suggested that temporal and spatial voltage differences characterized electricity access on the local distribution system. For instance: "Electricity is variable - it cuts out, then comes back. This can be like four times [in a day]." Others agreed that "electricity goes up and down [without warning]" (see Methods). A refrigerator salesman explained spatial variation, saying that, "if you are far away from the transformer, then the electricity the household gets is less stable than if you were closer to the transformer."

Voltage monitoring measurements across the island (see Figure 3.1) revealed localized voltage fluctuations as well as regional disparities, with some houses experiencing levels well below the island's nominal voltage of 220V. Figure 3.2 shows voltage profiles for two households connected to the same distribution feeder, with one transformer. The household towards the end of the feeder (further from the transformer) experienced lower average voltage and significantly worse fluctuations, dropping as low as 155 V (30% below nominal). In such an environment, customer loads and electrical equipment are not expected to operate reliably or as designed [40].

For a more granular view, we instrumented households in two sites (A and B) with low-cost voltage sensors (Figure 3.3). The sites had similar socioeconomic status but were located on distinct parts of Unguja's grid; results from two different feeders are more robust than those from a single feeder (see Appendix). We collected voltage data between December 2016 and June 2017. Each sensor is represented by a letter in Figure 3.3, with Sensor (a) closest to the transformer. Figures 3.4 and 3.5 show the voltage drops across the sensors for each site, with the Y-axis showing per unit (PU) voltage (voltage measured divided by nominal voltage (220 V)). The dotted grey lines represent +/- 10% of nominal voltage (1.1 to 0.9 in PU). Although voltage profiles at each sensor varied from week to week, there is a general dropping trend with distance from the transformer. However, voltage does not drop monotonically down the feeder; the time of day clearly matters (Figure 3.2). Furthermore, in Site B, Sensor (e) captured mean and maximum voltages higher than at Sensors (c) and (d) (Figure 3.5).

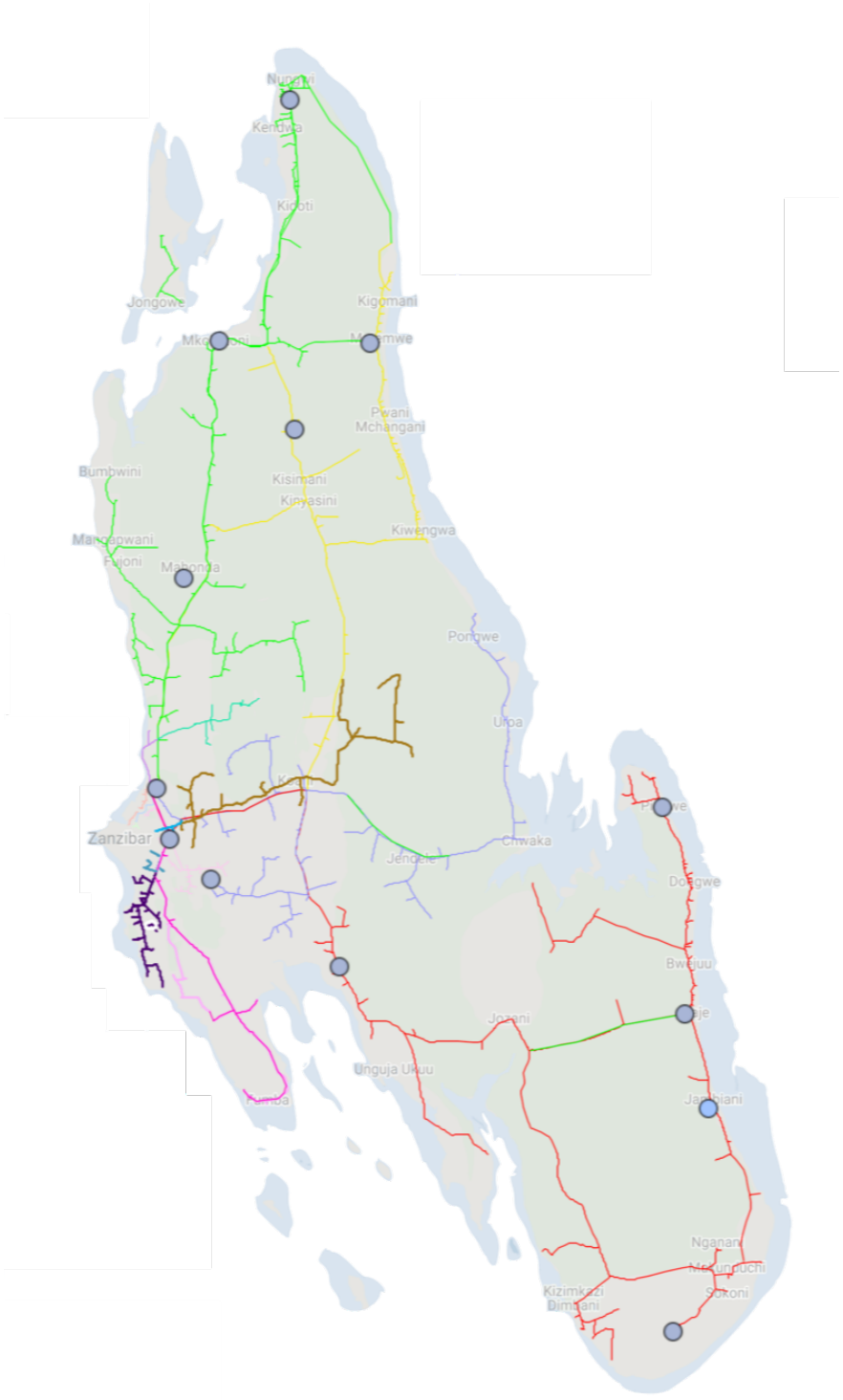


Figure 3.1: Map of Unguja with approximate grid-schematic. Dots indicate regions where interviews took place, while squares indicate regions where initial voltage measurements took place [60].

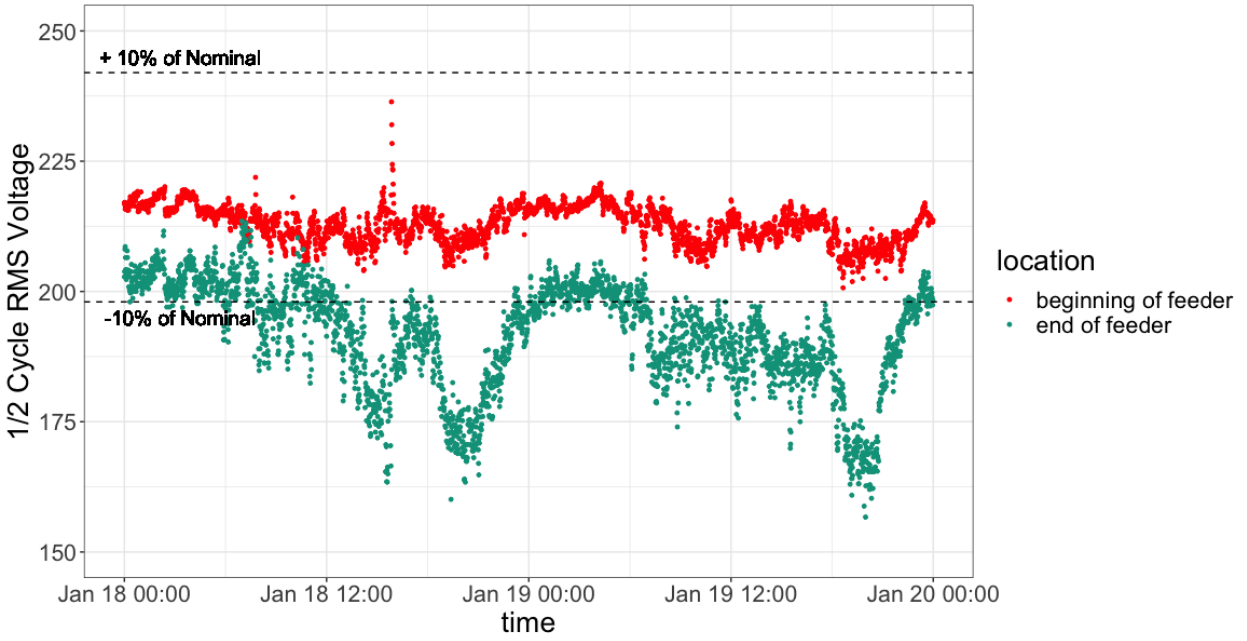


Figure 3.2: Voltage measurements at two households on the same distribution feeder taken in January, 2017. The dashed lines indicate +/-10 % of the nominal voltage (220 Volt).

These voltage fluctuations are outside of the range of acceptability by any standard we are aware of. However, as low voltages affect end-use devices differently, these measurements alone are insufficient to understand the effect that constrained grids have on customers. For example, one interviewee said that his voltage always dropped when his neighbor used his welders, while others did not recall any voltage variability. To explore these effects further we conducted detailed household surveys on customer experiences and perceptions.

How Power Quality Variation is Experienced

Surveys from 151 households revealed an array of damaged electrical appliances, from fridges to lightbulbs, across all socioeconomic strata. Pooled results from sites A and B revealed similar losses of appliances. Thirty-eight households identified appliances in their home that were not working. Five of these households had multiple broken appliances, such as fluorescent lights, fans, radios, televisions, electric cookers, refrigerators, and irons. One interviewee reported that his fridge had broken after a power surge. Another agreed, noting that after a power outage, he came home to a broken television and fridge. Asked about the life-span of light-bulbs, one participant replied, "usually they last about three months. Electricity goes up and down, up and down... so they never last [as advertised]." Many interviewees echoed this observation. An electric appliance shopkeeper noted that when customers purchased a fridge without a voltage stabilizer, they often returned to the store,

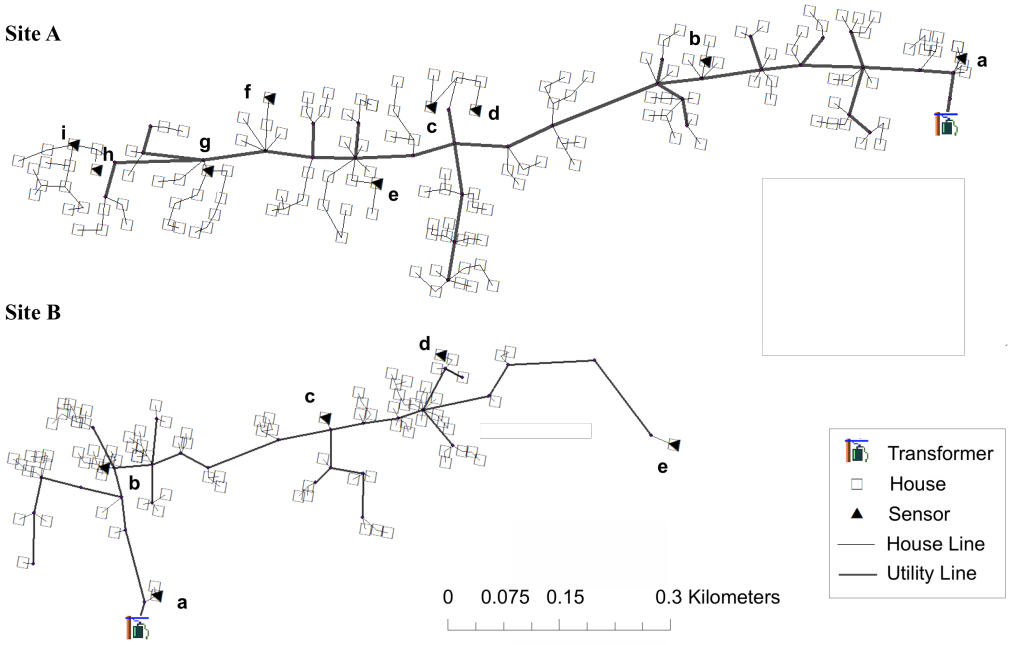


Figure 3.3: Distribution map of sites A and B with approximate location of households and sensor placements identified by letters.

fridge broken. Even low-end fridge stabilizers on the island cost 20 USD, or up to 40% of the 2013 monthly income. Another participant explained, however, that a voltage stabilizer was not a guarantee against material loss: "I was using a stabilizer. There was a short in the stabilizer so the current went straight through. I lost everything."

We cannot establish causality between poor power quality and the damage to these respondents' appliances; appliances break for many reasons other than voltage fluctuations. But our voltage measurements revealed periods in which voltage was well below the standard of 10% of nominal [33], which can, and does, lead to damaged appliances [25, 39, 52].

Respondents were asked if they recalled any voltage-related problems in the past month. Reported voltage-related problems included everyday inconveniences such as dimming lights to the point that it was difficult to see, fans growing softer and "weaker," insufficient power for large appliances, and sudden voltage spikes that damaged appliances. Households were also asked to identify the three most severe problems associated with their electricity connection; the menu of response choices included voltage problems, billing, maintenance, utility

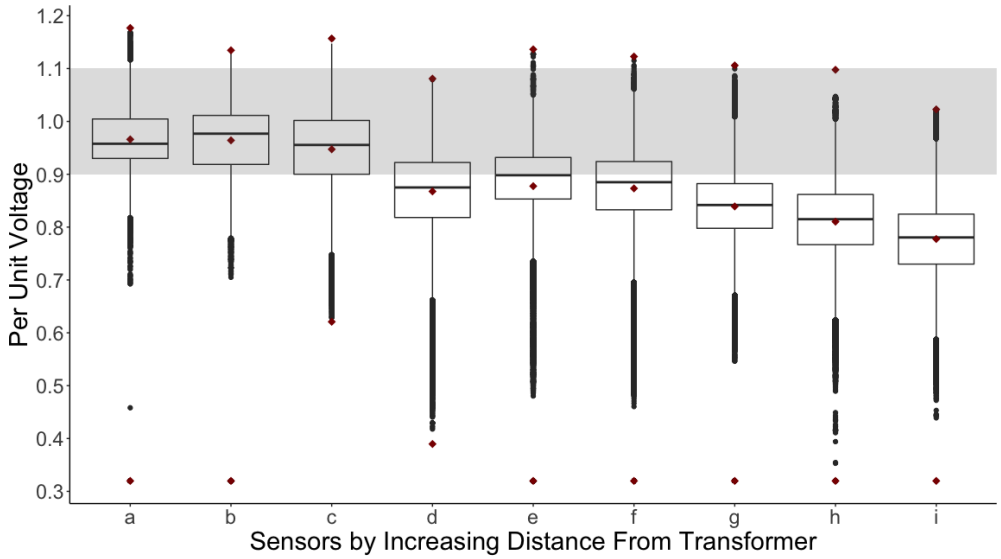


Figure 3.4: Per unit voltage (base 220 V) measured at corresponding sensor location in Site A. Black dots represent measured observations, averaged over one min. Red diamonds represent maximum, mean, and minimum voltage, without outlier observations and zero-measurements. Shaded region indicates +/-10 % of nominal voltage.

problems, and several others (details in Appendix). We assigned a per unit (PU) voltage to each survey response based on the mean PU voltage of the sensor closest to the respondent's household (see Figure 3.4 and 3.5, and Appendix for further details). Figure 3.6 shows responses, pooled for both sites, to the two questions based on their given PU voltage. While we found no clear pattern associated with experiences of voltage-related trouble in general (Figure 3.6, graph on the left), we found a positive trend between households' perceptions of voltage as a top problem and power quality (Figure 3.6, graph on the right). Specifically, for those that identified voltage fluctuations as a top concern, our measurements indeed corroborated their low power quality.

The appliances people owned also correlated with their perceptions of voltage quality. Those who owned only low-tier appliances (e.g. lights, televisions, or irons), which are common and less sensitive to voltage fluctuations, tended to raise fewer concerns about voltage than those who owned top-tier appliances such as fridges, freezers, or blenders. Figure 3.7 shows that eight out of 52 (15%) participants who owned only low-tier appliances considered voltage-related problems a top concern, compared with 44 out of 99 (44%) with top-tier appliances.

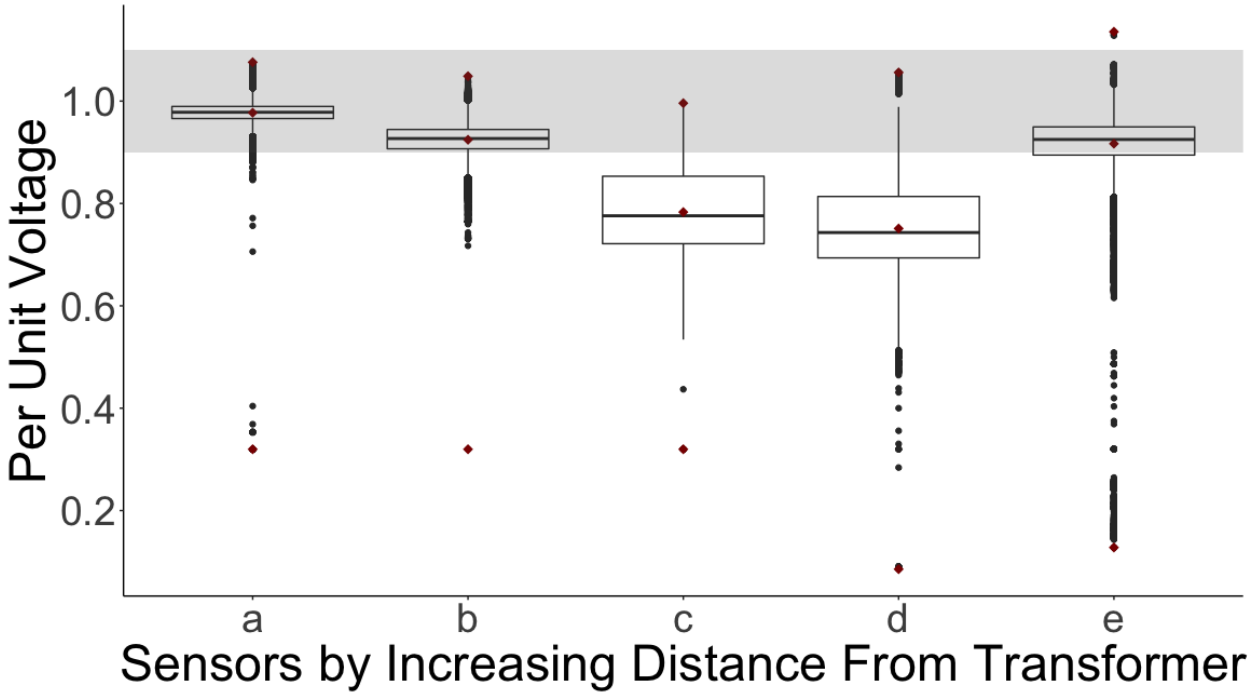


Figure 3.5: Per unit voltage (base 220 V) measured at corresponding sensor location in Site A. Black dots represent measured observations, averaged over one min. Red diamonds represent maximum, mean, and minimum voltage, without outlier observations and zero-measurements. Shaded region indicates +/-10 % of nominal voltage.

Discussion

This study provides household-level insights into the nature of electricity access in constrained systems, using Unguja, Tanzania, as an illustrative case. We found that the quality of electricity varied significantly for households connected to these grids. We captured extreme voltage fluctuations during certain hours, showing that, in these capacity-constrained conditions, when and how others on the same distribution line consume matter greatly for an individual household. Without boosters and voltage regulators, which utilities often do not provide, and without in-home ways to mitigate voltage drops, which low-income communities cannot afford, households further down the feeder experienced worse voltage fluctuations than those near the transformer. Although some drops and fluctuations in voltage occur in all systems, the drastic voltage fluctuations across both sample sites indicate pervasive inconveniences and the risk of costly damages, undermining the promise of both adequacy and equity that universal connectivity is supposed to promote.

Our voltage measurements and household surveys show that having an electricity connection (i.e. access) is not at all the same as having a reliable or adequate electricity service (see [86]). While rarely analyzed in the electricity and development literature, our work shows

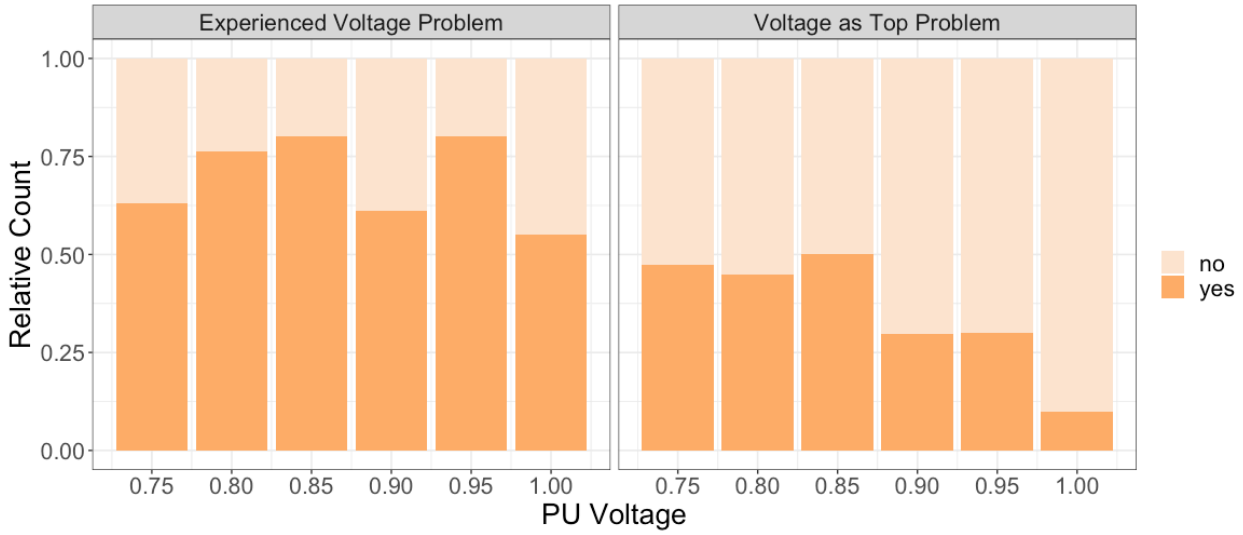


Figure 3.6: Survey responses for both Sites A and B versus mean PU voltage associated with participating house (i.e. the mean PU voltage at nearest sensor, rounded to nearest .5 Volt - see Appendix for further details). The graph on the left shows responses to the question: did your home experience voltage fluctuations in the last month? The right shows whether a participant noted voltage as a top concern when asked: what are the most severe electricity-related concerns? We note that some respondents may "normalize" the condition of uneven voltage, and may therefore say they are not experiencing voltage problems. If so, the number of those who report experiencing no voltage problems may be an undercount.

the many ways in which power quality and unreliability matter to low-income communities. The quality of electricity services shapes households' ability to use their "access." In Unguja, households reported lights that were too dim to be useful, larger appliances that could not be operated, and fridges that could not reliably store food. Low or extreme voltage can mean needing to replace appliances more frequently or purchase voltage stabilizers, resulting in higher costs for an already cash-constrained population. It can mean not being able to rely on appliances that have been purchased; even with a fridge a household may need to shop and cook daily, or even with an electric cooker the biomass stove cannot be retired. While those respondents who considered voltage quality a top problem tended to have top-tier appliances, even those with more common electrical appliances were impacted by poor power quality. Households from all socioeconomic strata indicated that they would consider paying more for better quality service.

Unguja is only one of many communities where resource-constrained utilities strive to provide electricity to cash-poor consumers. In Kenya, for example, an increase in the number of household connections "has been matched by an equally sharp decrease in average residential consumption" [101, p. 8]. Our findings suggest that inadequate power quality

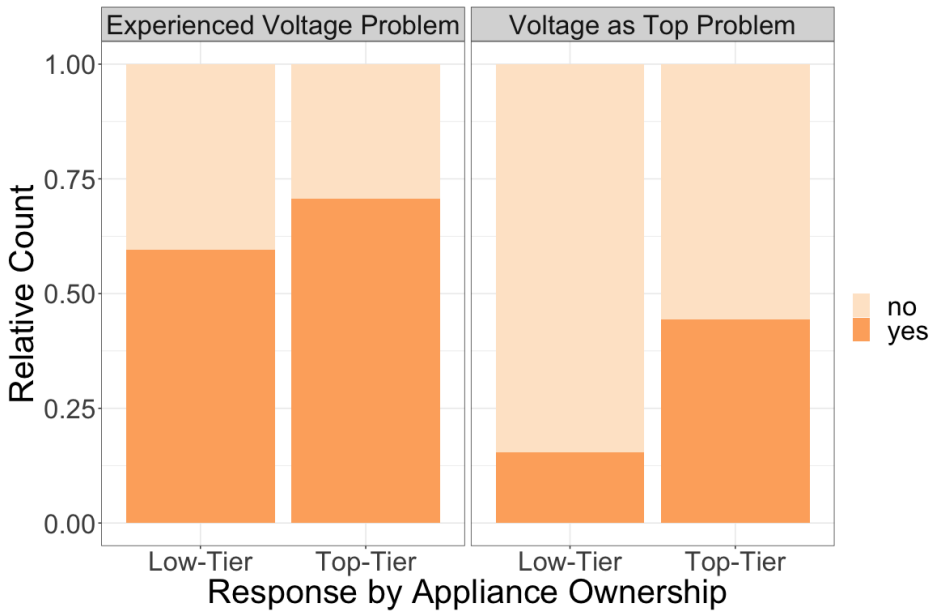


Figure 3.7: Survey responses for both Sites A and B related to voltage by appliance ownership. Participants divided by low-tier electrical appliances (lights, TVs, irons) and top-tier electrical appliances (fridges, freezers, blenders).

on the supply side limits consumption by damaging appliances or discouraging consumers from buying others that they may wish to use. In turn, low consumption contributes to low cost-recovery, potentially constraining the utility's capacity to invest in infrastructure, such as line voltage regulators or distributed energy sources sited close to the customers [83], that could deliver better power quality. This negative feedback between utility revenue and consumer demand highlights the consequences of the financial pressure that utilities and consumers face as grid systems spread (see also [23]).

Our findings reveal that power quality (or a lack thereof), measured here as voltage magnitude and variability, is an essential factor in determining the benefits that electrification can deliver. On the Unguja grid, the ability to benefit from the basic accoutrements of modern life – exactly what universal access to modern energy services aspires to provide – is not guaranteed. In the quest to attain "modern energy for all," therefore, energy and development scholars must take seriously what constrained grids are actually able to offer SSA communities. While these systems undoubtedly offer increasing opportunities, they do so at present in ways that are neither adequate nor equitable.

Chapter 4

Modern Energy for All? An Ethnography of Expectations and Experiences

4.1 Introduction

Ah! una microwave, unaitumia? "Do you use it?" I asked. I was surprised to see one. Microwaves are not common appliances in the majority of homes in the Zanzibar archipelago or the rest of sub-Saharan Africa (SSA) for that matter. The elderly woman I spoke with was the head of the relatively middle-income household. Her husband had died and she supported her family with money she received from running a small cooking business out of her home. *Imeharibika mbovu*, she responded. "It broke, it's damaged." She explained how her microwave experienced an electric short, then stopped working. Her fridge had shared a similar fate – she guessed it was the fridge's *gesi* that finally gave out – a reference to the fridge's compressor. The compressor does the work of keeping a fridge cool: it moves around a cold refrigerant gas in liquid form by way of a pump and electric motor. The latter converts electric current into mechanical work and is found in other household appliances, like blenders, fans, and microwaves. Because electric motors rely on a certain predetermined voltage to function properly, erratic voltage fluctuations found on the island – sometimes too high, too low, or simply too unstable – shorten its life: i.e. the *gesi* in fridges gives out. Fridges are considerably more common in Zanzibar than microwaves, though how they are used when not damaged often depends on being able to afford the electricity it consumes. For this woman, patterns of electricity use were conditioned by affordability. Having a prepaid meter that forced her to pay for "units" or kWhs prior to consuming electricity meant that the way she used a working appliance depended on how much money she had been able to bring in previously. Ultimately, the one thing she was anxious to avoid was *mnabaki kiza* – remaining in darkness – so keeping her prepaid meter from running out of units was her top priority.

This woman's experience captures the nature of modern energy services in the Global South: the norm of living with poor quality and expensive electricity access – what I am terming (un)reliability. This picture contrasts with that of the Global North, where affordable and reliable supply are the expectations and experiences of electricity services. The contrasting norms resonate with electricity scholarship more generally, which leans on an old global dichotomy: infrastructure in the Global South is largely marked by failures while in the North it is successful and taken-for-granted, with the latter serving as a benchmark for the former. Electricity systems of the Global North are characterized by cheap, stable, present, or *invisible systems*, while Global South services are characterized by expensive, erratic, absent, or *visible* systems. In the prevailing narrative, low-income residents, particularly in sub-Saharan Africa (SSA) and south Asia, are tacitly understood to be "able to cope" or fortunate in spite of (un)reliability – because "a little goes a long way." Simultaneously, these same users are typically cast by donors and international agencies as partially to blame for failing electrical systems – accused of not consuming enough or simply being unwilling to pay for the service, i.e. stealing. In contrast, episodic (un)reliability is a state of crisis for many residents in wealthy countries, like those in the United States, and is reflected as such in media and institutional discourse. By exploring (un)reliability discourse across the globe, I attempt to move past the oversimplified, prescriptive narrative of a "little goes a long way" in the Global South, by showcasing how communities hold different values about access standards for different regions.

While efforts are being made to develop a more nuanced perspective on what it means to have an electricity connection, development goals such as "modern energy for all" under Sustainable Development Goal 7 (SDG 7) remain largely binary, categorizing households as either having or lacking connection, without serious regards for service reliability or service type. Because of this bias towards increasing the availability of electricity connections rather than quality of connection or services, STEM-oriented sustainable development research (such as the growing fields of development engineering, development economics, and sustainability science) often overlooks an important aspect of electrification: *the spread of unreliable and unaffordable electricity services, and burdens and responsibilities placed on individual users as a result, are threatening its supposed benefit for a cleaner and more modern future.*

This contradiction serves as a catalyst for the questions and research in the following pages. As I see it, the techniques and politics of how electricity services are promoted in the Global South are at times antagonistic to the purported benefits of having these services to begin with. The deficits of these services are so common that they have become internalized, anticipated, and ultimately expected, creating the conditions by which problematic practices go unnoticed.

Analyzing (un)reliability as a fundamental condition of contemporary electricity development offers an important opportunity to reconcile the disconnect between an electrification-of-everything discourse that places an inherent goodness in the connection itself and the intent of the Sustainable Development Goals. It forces researchers and the energy policy community to interrogate the kind of development that is delivered through intermittent

transmission, leading to a critical question:

What level of access is actually required to accomplish SDG 7?

In answering this question, we will inevitably find that expectations are embedded in socio-material histories, past and present. We will be left to grapple with another important question:

What are the implications of taking expectations, or lack of them, seriously?

These questions are important for interpreting the development project broadly, as well as at a more granular level, for contextualizing the widespread expectation of cost-recovery from users of electricity services.

I approach these questions through an ethnographic lens. I first identify prominent value-laden discourses about electricity in SSA by outsiders through anecdotes and prominent scholarship and set them parallel to articulations of electricity usage in Tanzania. I then examine literature and methodology before turning to the main thrust of this work: an analysis of three years of ethnographic fieldwork in Unguja, Tanzania started in 2014.

4.2 "Lighting Up Africa": Discourse Across the Globe

The titles of two Economist articles, "*Lighting up Africa:* How electricity will transform the continent" and "*Lighting a dark continent:* The power shortages that have been holding Africa back are at last easing," from 2013 and 2014 respectively, reflect not only a contemporary development preoccupation with sub-Saharan Africa's electrification status, but also a deep-rooted, historical set of relations between the Westerner and the non-Western world. Conjuring of a civilizing mission notwithstanding, these articles from a prominent international magazine speak to a global electricity access community made up of scholars, policy makers, and government and non-government actors alike, who are resolved to spread electricity connections in SSA and south Asia, mobilizing billions and billions of dollars in the process. The electricity system in Zanzibar itself grew out of large investments by a Norwegian development organization, the World Bank Group, among others. And according to a 2017 IMF report, nine electricity-related projects in Asia and Africa from 2010 to 2016 have been valued at over 1 billion US dollars, a mix of private-public investment [69].

The driving assumption behind these high-value, multi-actor initiatives is that electricity is inherently good. After all, electricity can be green while getting people out of poverty. More recently, scientists, policy makers, and activists have been explicitly promoting an increased reliance on electricity for tackling climate change (e.g. electrification of vehicles and home heating and cooking) and poverty (e.g. expanding grid systems and decentralized, off-grid technologies). In contrast to large generation projects like hydroelectric dams in Ethiopia and Ghana or other large-scale electricity-related infrastructure, the push to "bring electricity the last mile" through decentralized efforts has largely avoided criticism. But the

peculiarities of the off-grid movement, electricity's ties to renewables and poverty alleviation, and large inflow of capital and foreign actors, have led to such remarks as "There's more than a whiff of colonialism about the rush of Westerners and western money into Africa'" [113].

Moreover, despite the concentrated efforts and investments underpinning SDG 7 – "modern energy for all" – low-income countries face persistent (un)reliability. Even in high-income countries, a rise in extreme weather conditions coupled with aging infrastructure has triggered outages and intermittency for residents accustomed to the highest levels of service reliability. In SSA, the failure of centralized grid systems to provide cheap(er) and more reliable services is emphasized by advocates of off-grid technologies [77], even if it is unclear whether electricity systems such as on-site solar can meet the level of electricity access SDG 7 might very well require.

***

"Households? They can cope with poor quality electricity." This was the response I received after I reached out to an electric-power systems engineer consulting for the Zanzibar electricity utility ZECO in the spring of 2016 when I spoke with him about my plan to research voltage spikes, dips, and sags in the region. His words conveyed a sense of detachment, my research interest a nonissue. Yet for me, his response became an important catalyst for the critical research on access found in these pages. Since 2010, I have been taking stock of (un)reliability in Tanzania, watching it wreak havoc on household appliances in homes, schools, and workplaces, or simply leaving electrical appliances unused. I have been wondering what the life of an energy efficient lightbulb would look like under extreme voltage conditions. I have been asking myself why people would (re)purchase electrical appliances of any kind, particularly those of higher cost, if they had "a history of breakage." More recently, affordability and intermittency have been gaining traction in access scholarship, but quality has largely been overlooked. Over the course of six years, propelled by the value-laden terminology I encountered in that initial conversation with the electricity engineer, I have paid careful attention to the ways in which (un)reliability is discussed inside and outside the spaces in which development projects function and are experienced. With individuals in seminars, conferences, and informal one-on-one chats, with electricity-access researchers, policy-makers, engineers, and consultants, I have encountered value-laden commentary frequently.

> "Electricity for televisions? We shouldn't be spending money for that type of access."
>
> "You know the problem with grid systems in Africa is everyone there steals."
>
> "Well, it might not be perfect, but a little goes a long way."

These sentiments, echoed in reports, newspapers, government documents, and academic literature, are emblematic of a broader narrative preoccupying energy access scholarship:

electricity investments should prioritize productive uses, residents in predominantly African and Asian countries have an entitlement problem, poor people can cope. These "outsiders" (including myself) are people who embody material and social conditions outside the spaces (un)reliability unfolds. In homes, businesses, street corners, shops, and offices in Unguja, Tanzania, the largest island in the Zanzibar archipelago, I have simultaneously taken note of residents' own articulation of what it means to "cope" with (un)reliability.

> "I only use the electric oven every once in a while, it's for making bread for my family."
>
> "I prefer the prepaid meter, that way I can use what I can afford."
>
> "If the lights go out, I'll just use candles."

Pitted against the engineer's blunt response about coping, or others' curt characterization of access, these sentiments reveal a stark level of incommensurability in the ways (un)reliability is valued across different actors and communities with varying degrees of responsibilities, power, and burdens.

Electricity for Productive Use

The opening line of a 2018 short opinion on the website Power for All reads: "Productive use is one of the hottest buzzwords in the world of energy access today, increasingly used by development banks, industry leaders, and civil society organizations (among others!)" [153]. The author's remarks suggest a novelty in linking productive activities, or more broadly – economic growth, to energy access, yet it has been a go-to motivator for electrification scholarship and research for quite some time (see, for example, [72, 32, 124]). Efforts have been made to problematize what is seen as preoccupation with "linking [rural electrification] development with productive uses for energy" without much evidence [34]. Paul Cook attests there is no consensus about whether or not electricity consumption is causally linked to economic growth or even the direction of causality (see also [128]). The finding echoes more recent scholarship. Burlig and Preonas [30], for instance, observe that although rural electrification brought an increase in nighttime brightness in villages in India, it did not "yield even modest changes in labor, income, household wealth, asset ownership and expenditures, village-level outcomes, and education" (p 38) (see also [102] for a study on Rwanda).

Nevertheless, the link remains entrenched in electricity access scholarship. In the short Power for All opinion piece, the author expresses his frustration at the "increasingly unifying principle for defining something as productive," that is, if it generates new income (see, for example, [134]). He asks what does "productive use" of energy actually mean? and posits that electricity has the potential to improve livelihoods through a slew of appliances not generally considered productive such as TVs, lighting, and fans. While Bhatia and Angelou [21] categorize these appliances as the type of access needed "inside the household," for "lighting, air circulation, entertainment, communication," etc., as opposed to a type of access needed "outside" the household, access for productive uses (p 58), they still motivate their discussion

on energy access in the household by alluding to the "strong evidence that electricity facilitates social and economic development." (A cursory glance through their citations reveals that, unsurprisingly, the evidence is not so strong.) The opinion piece itself ends up advocating for decentralized technologies that offer minimal level of access because "new data" show low-consuming electricity appliances can provide income for some individuals. For example, in two anecdotes, people experience newfound income through television ownership as community members pay to watch their TVs. Importantly, monetizing television use is only possible because others do not have electricity access or the same level of access. Though, of course, anyone who reads scholarship on electricity in SSA and south Asia knows that uneven access is to be expected for households in the region.

Electricity Entitlement

The persistent nature of unaffordable and unreliable access in countries where most electricity services are subsidized has given way to another important discourse: that of electricity entitlement. The provocative title "Electricity is Not a Right" of a 2019 article published by the Becker Friedman Institute of Economists – whose authors hail from some the most powerful and prestigious universities in the World: University of Chicago, London School of Economics, Yale, and Stanford – does not actually speak to the debate of whether or not electricity is a right. Rather, it casts people in the Global South as having an entitlement problem. Specifically, the authors argue that because governments in Africa and Asia subsidize electricity, people do not feel they need to pay for their service, i.e. they resort to theft or nonpayment "in a world where electricity is still broadly seen as an entitlement."

These authors align with policymakers, who blame a "culture" of nonpayment for Global South infrastructural woes (see, for instance, [137, p 122], [27, p 100]. While some of these same reports note that a large, if not majority, of non-payments come from government institutions such as police stations and ministry offices, residents are the main focus of certain technological interventions like the prepaid [86]. The politics of disconnecting large debtors who hold more sway over utilities is ostensibly a more challenging barrier than engaging with individual households.

Coping with (Un)reliability

The specific idea that "households can cope" with any type of access tends to be articulated most clearly in informal conversations as opposed to formal publications, but the quantity and focus of scholarship on (un)reliability is a testament to the ways in which having to live with or get used to poor quality and costly services has been normalized for households across the regions, particularly for "inside" household activities. One of the clearest indications of the assumption that households can cope is the sheer volume of reliability scholarship focusing primarily on business and firms, even though faulty electric systems serve households and businesses alike [87]. The studies that do consider the impacts of unreliability on households

often concentrate on implications for household productivity, and not necessarily comfort and overall ease-of-life (see, for example, [29, 7]).

Another way this narrative is perpetuated is through the belief that any additional electricity project or effort in the name of universal access is a unidirectional move towards a better life. Over the last five years, a framework has emerged, tied to the World Bank Group, to catalog and characterize persistent (un)reliability vis-à-vis household access in terms of "tiers" [21]. Any tier other than 5 – the highest tier in which one can afford any "high-power" appliance with minimal to no interruptions or voltage quality issues – is considered one of the "interim" tiers, explicitly called such by at least one report [99, p xiii]. This description is notable because it casts non-ideal access as a temporary condition; one must simply wait until movement upwards. Similar to the "multi-tier" framework, calls to promote decentralized, off-grid technologies in light of no access, or "deprived" access (see, for example, [32, 67]) also reflect the assumption of goodness in any of these initiatives. Though not equivalent at all, these off-grid technologies and projects are discursively equivalent. Ultimately, what much of the scholarship has in common is the assumption that electricity access is a completely benevolent project, even if electricity infrastructure and the services it renders across these regions have never been considered adequate or reliable, or even proven "good" for poor communities. It is this assumption of goodness in any and all electricity projects that reinforces the narrative that "a little goes a long way" and poor people can cope with (un)reliability.

4.3 The Political Economy of Unreliable and Unaffordable Access

In this paper, I reflect on the implicit values and expectations surrounding power and reliability embedded in the Sustainable Development Goals (SDGs) through critiquing global energy discourse(s) and the dichotomies therein. This work takes an ethnographic approach to understanding and comparing electricity access across multiple geographies with distinct politics, expectations, and supposed values. *It subscribes to an understanding of electricity access not as a binary phenomenon but as a relational phenomenon between users, service providers, and the service itself* [151, 86].

While using a relational framework, I take up the call for an ethnography of infrastructure (following Star [151] and Gupta [68]) and bridge it with the scholarship of large (socio)technical systems (LTS) popularized by Hughes [80] and the scholarship on the political economy of development. The former contextualizes technical systems as both socially constructed as well as shaping the society within which they are embedded; the latter sees these large infrastructure systems as contributing to state control (cf. Scott [146]) but also to state legitimacy [2] – at first of the colonial state in Asia and Africa but subsequently of the postcolonial state, which retained many practices of the past. Thus, I add to the literature by connecting everyday practices to world systems and knowledge, and attend to

the historical and cultural context through which "modern energy for all" and sustainable development discourses and practices operate.

Working in the context of sub-Saharan African development, this work retains the understanding of energy infrastructures as complex socio-technical systems that stood for the power and largesse of the state in colonial as well as postcolonial periods. However, it goes beyond the perspective of the system builders to "see" not like the state but like the lay user of electricity services. It brings the twin lenses of socio-technology and postcolonial developments to understanding the relationship that users have to their energy services, the role of culture, and how that relationship is shaped by conditions and normalization of (un)reliability. I argue that this lens is a form of "seeing the state" [35] and provides a way to theorize intermittency as a lived experience in sub-Saharan Africa.

I bring these theoretical insights to bear on the costs of intermittency and the value of reliability in a context where intermittency is normalized. Specifically, I argue that the energy policy literature, which treats users' "coping costs" as a way to make up for inadvertent deficiencies in an unreliable electricity system – again, benchmarked against an idealized reliable and abundant service – actually conceals the extent to which coping is a fully anticipated and expected response to an electricity system that is built to be rationed, on the understanding that "a little goes a long way" when you have nothing to start with. Highlighting the concept of "coping" also allows us to engage with the STS-inspired literature on the constant adaptation that intermittent infrastructure calls for, such as turning off the fridge to protect against a voltage spike and the mental cost-benefit calculations that are necessary on a daily basis to "cope" (cf. Trovalla and Trovalla [165]). Thus, I believe that this work will make a theoretical contribution to understanding the energy and development process not from the "top," but from "below" in relation to the top-down view, and also to understanding how to think about "coping", a ubiquitous word in the water and energy policy literatures in low to middle income countries.

4.4 (Un)reliablity from Unguja, Tanzania

To return to answering the question raised near the outset of this paper, namely, *what level of access is required to accomplish SDG 7*, one might begin by imagining what the goal is trying to avoid: first, the use of dirty fuels (whether that is through large generation or biomass fuels in the home); second, and more implicit, a type of access that does not require the input of significant labor. Clean energy access at the household or community level should not require substantial work or conditions that would prevent people from living a convenient life. Because the goal is not the clean energy form itself – but rather what energy offers – it should not require much effort to turn a light on or power a fan. And although modern energy is not strictly electricity (after all, liquefied petroleum gas (lpg) provides a relatively clean and convenient way to cook), electricity systems remain a dominant paradigm for modern energy access. One only has to look at the symbol of SDG 7 – the lightbulb – to understand electricity's central role. Still, while these key "avoidances" arguably (and

perhaps rightly) propel the fervent support for SDG 7, individuals' own articulations form a fundamental understanding of what access *should* look like. Simultaneously, these individual perspectives are not "personae," that is they are also grounded in the normality of the community; expectations are culturally and materially grounded.

The reflections on expectations and experiences from those living "inside" Unguja come from semi-structured interviews and participant observation conducted over the course of 14 months. From the summer of 2013 to 2018, I conducted 57 related interviews, mainly with households, but also some small and medium sized businesses, hospitals, schools, and electric utility members. Importantly, the unit of analysis is not the household or business or school itself but *the individual* with their own relationships to electricity systems. The semi-structured interviews revolved around experiences with (un)reliability as a whole, including payment mechanisms, intermittency, outages, and quality of supply; not being able to afford electricity or being connected to an unreliable service often led to the same outcome and thus complicated the separation of affordability and reliability. A fuse can be taken out manually by a utility worker, say because a user does not pay their bill on time, or burned through from a spike in electrical current. Either way, the user bears the burden of having it replaced.

In what follows, I describe and synthesize accounts of everyday life of residents living in Unguja, Tanzania as they relate to the discursive, outsider narratives of "modern energy for all." Importantly, I use (un)reliability – taken as unaffordability, intermittency (announced and unannounced outages), and poor power quality – to shed light on the ways people engage with and make sense of their electricity services. Specifically, (un)reliability takes the form of disconnections, either through running out of units with a prepaid meter, building up debt and being cut off by the utility with a postpaid meter, and/or in the form of outages and extreme voltage fluctuations. The conversations generated by these socio-material realities reveal fundamental desires that people have for their electricity services. These "insider" accounts are grouped into three categories that run counter to the commentary from "outsiders" described above: the importance of "non-productive" practices with respect to people's electricity appliances; people's relationships to payments and notions of "entitlements"; and lastly what it means for Unguja residents to cope with their current forms of access.

Umeme (Electricity) Not Just for Productive Uses

In the late hours of the night, back when he was still living in *mjini* (the Swahili name for a city/urban space, or in Unguja, the region of Stone Town) he would turn the TV on. A farmer with a family of six, he had since moved to a rural community in the center of the island. At their new home, *umeme ni shwari* – an informal way to say electricity is stable, akin to smooth waves. (From a physics perspective, the term *shwari*, smooth wave, is completely appropriate.) But in *mjini*, starting around six pm they had *umeme mdogo*, small electricity. He knew it was a problem with the transformer, not enough capacity to keep up with electricity usage in his neighborhood during "peak" hours. During peak hours,

when usage nears the transformer limit of operation, those "waves" of electricity become more extreme and less stable, or just plain insufficient to power certain appliances. (Low voltage is the more specific physical manifestation of *umeme mdogo*.) Around six p.m. people would come home and turn on their lights, their boilers, their TVs, fans, and maybe their electric cookers. So the farmer and his family waited until midnight to watch TV.

The centrality of television in people's lives is readily apparent in Unguja. After light-bulbs, TVs are the most common appliance you will find in homes (see Fig. 2.2 in Chapter 2); and while immovable furniture (couches, tables, shelving units) has long been a sign of wealth in SSA, TVs, it seems, are not markers of wealth to the same degree. In a home in Welezo, an urban community in the outskirts of Stone Town, a young man spoke about his and his family's relationship to electricity. I sat across from him on their cold cement floor with my back against the wall. I took in the house's vast living space, its sturdy walls and floors, themselves signs of a certain socioeconomic status. There was no furniture in sight, no couches, no tables, no curtains, no doors, no wall art, nothing on the floor except a small mat in the center of one of the two living rooms. To my surprise, pushed up against the wall, opposite the entrance door, I spotted a large television. That I did not expect to see a TV in this otherwise bare space represented a misguided assumption on how a household accumulates stuff – a preconditioned imaginary of wants and needs, their hierarchies and associated material forms. For whatever reason, although the family had lived there since "sometime in the past," there was still no furniture in sight, just a large TV in the front room and a refrigerator in the back room.

Slightly more north and on the western coast, I sat in another home, this time with quite a bit of furniture but less physical space. "So what electricity appliances do you use?" I asked the elderly male head-of-household. "I see you have lights..." I started. "I have lights, an oven, an iron, a blender. I have a mixer to make bread, and I have refrigerators." He ran a small duka, a convenience store, which was attached to his house. I imagined the refrigerators, bread maker and oven were used for his business, for productive uses. Indeed, he said he sold sodas and juices, but "the oven and the mixer?" I inquired. "I don't sell bread," he responded. "[The oven] is only for the family...you can make some *maandazi* [small breads] on holidays. It makes people happy." This idea of reserving the use of an electric appliance for holidays in particular is not lost on others: it is during Ramadan, the holiday of togetherness celebrated by the majority Muslim, Zanzibari people, that many find their electricity usage "going way up."

I pressed the man again on whether or not he would eventually use the oven for his business, but he stayed firm: "it's for making people happy, it's for the family only." It was not to be used often of course, "ovens take a lot of heat" and he, like everyone else, was worried about his electricity bill. Nevertheless, his wife recently purchased the used oven for 200,000 Tanzanian shillings (TZS) (100 USD) and for the time being, it was to make his family happy. Of course there were appliances in Unguja homes being used for running small enterprises and bringing in some money, but a significant portion of electricity-related preoccupations revolved around individual comfort and security.

In a system with prepaid meters and where money is tight, the hierarchy of needs and

wants vis-à-vis electricity appliances can be captured by one simple calculation. If "units'" are running low or are completely out, what devices are necessary? Or to put it differently, if you had to choose one device to use, which one would it be? "In our houses, without fans, we cannot get sleep" a retired veteran declared. We were having a conversation about his household's shared prepaid meter; he lived with roommates. In his account, the "little amount of money" they had they prioritized for topping up their prepaid meter. After all, they had to be able to use their fans during "excessive heat," he tells me. While fans are important, the most common answer is lights. Perhaps it is no surprise that they are number one on the list of devices people need when money is tight. Without much in the way of street lighting, except in some more touristy areas in Stone Town or larger intersections, businesses and households alike place high value on keeping them on, especially for security. A woman living with her five children, young and old, and her elderly father summed it up: *Siwezi kulala giza* – "I can't sleep in the dark."

Entitlement Counter Narratives

The subtext was laid thick in the portrayal of the new payment system sweeping Unguja and SSA, a clever-one liner by a school principal I was interviewing: *Haumbani mwananchi, mita wanazotumia ni mita za uwezo wa mwananchi.* "It frees up citizens – the meters [the government now] uses are the meters of a citizen's abilities," he told me. The translation of this particular phrase took some time because of its uncommon use of the term *haumbani*: the negative of the term *kumbana* – to struggle, jostle, make difficult. Affixed to a commodification process, *haumbani mwananchi* (citizen) translates as: to financially free up a citizen.

The new service, which relies on a prepaid electric meter forcing payment prior to usage and which does not require much interaction with Zanzibar's state-owned utility, is as much an individualizing process as it is financial. Countless others I interviewed relayed the similar sentiments as the principal. Now, they can use their "own limits," and use electricity according to their "own means." With this man's school having once accumulated debt totaling 700,000 TZS (350 USD), electricity being cut off because *his shillings* had run out was a positive. "You know," the principal continued, speaking of the new system, "*for me, for my shillings*, I add my units worth 2,000 TZS (approximately 1 USD), I use them until they are finished, and that's it. Electricity cuts off – that's it." He himself, or in this case, his school, can be free of ZECO services.

Conditioned to live without electricity, it is no surprise when people are so readily willing to give up their connection when money becomes tight, as in the case with the prepaid electric meter. This quick acceptance of a tool by relatively poor residents that disciplines through disconnections runs counter to blanket claims that people across sub-Saharan Africa and many parts in south Asia have a sense of entitlement to electricity services [86]. It is not lost on Unguja residents that these services are state services. *Serikali*, or the government, was often interchangeable with ZECO in many conversations. If we assume that citizens are entitled in states like Tanzania that offer up subsidized electricity services, then we would

also expect those entitled citizens to resist a technological tool that limits their ability to use that very service freely. And though places like South Africa might experience such contestation and retaliation (von Schnitzler 2008), in Unguja many people readily gave up their claim to state-subsidized, necessary services, if only for a short amount of time. Even this, however, only begins to describe what I experienced as the counter-narratives to a "culture of nonpayment."

"So for example, if I use just one burner for one hour, that's one unit of electricity." I was slightly taken aback by this man's precise account of how much electricity an electric cooker consumed. I had heard many times the claim that a prepaid meter gave people a sense of their electricity consumption (which appliances consume more electricity and by how much), but this man had a postpaid meter. He received a bill at the end of every month, telling him how much he owed and how much he consumed. He preferred it that way, he said, because his bill was manageable. For him to tell me the amount of kWh he expected a single burner to use was indicative of a meticulous arrangement he had established between how much he consumed and how much he could afford. Others had similar reactions to their monthly electricity bills. If debt occurred, *hamna shida*, "no problem," they said. They would pay it off little by little in order to continue using the small amounts of electricity they felt necessary (see [86]). Contrary to the assumptions of the development community, the people I encountered who preferred postpaid meters did not expect to benefit from electricity without payment. Instead, they carefully monitored and used electricity according to what they anticipated being able to afford. In Unguja, it would seem, the flip side of wanting to give up your electricity connection so readily, is wanting to maintain that connection because you know you can ultimately pay your bill.

What Coping Looks Like

He once owned a fridge but not now, he said. "It was a large [one]. Below the fridge above was the freezer." It broke the night before Christmas. He continued, "I left my place in the evening to go to church. When I returned I found everything broken." The leakage from the broken, thawed-out fridge spread throughout the house and into his bedroom. Luckily, his neighbors were around; he feared "everything would have burned" otherwise. He ended his story by telling me the surge also ruined his TV. It went through the voltage stabilizer he was using to prevent this very thing from happening. Hearing this account in the summer of 2015, interview number 20 or so, I felt a mixture of sadness and apathy. Sadness because I knew he worked long hours to save up the money he could (he had moved to Zanzibar from mainland Tanzania to work in hospitality), and apathy because I had heard similar stories before: it was not his alone.

The staggering number of broken appliances I found walking into homes in Unguja would be unbelievable to most Americans. There was the family with their electric oven tucked away in a corner, clothes stacked on top. A woman said it was mbovu, "Broken." In the same house, but in another corner, I spotted a fridge. "And that one?" I asked. "Broken as well," she replied. In another house I talked with a young woman whose husband lived in Dar es

Salaam and sent money to support her and their young kids. Relatively well off, they were one of two households I came across with an air conditioner. "Working?" "Nope." At a house with an older woman who took care of her kids and grandchildren, and one who had autism, I was struck by the sight of a washing machine: it was the only one I had seen throughout my interviews. She said, "oh that? It doesn't work." Others discussed their lost fans, radios, and blenders. A farmer told me that stabilizers "break often." His was a larger one, a newer model (I had seen them at the local store for about 50 USD), and it was on the floor in the corner of a dark room, broken, gathering dust. In an adjacent room sat his broken fridge. There was a casual manner by which people discussed their broken appliances – almost as if conditioned to the losses.

Why all this loss? It is difficult to say for sure how each appliance in Unguja breaks, but there is an array of possibilities which might jeopardize the life of an electrical appliance. To begin with, many appliances in low-income countries come from somewhere else; they have had another life [114, 121]. Yoshida and Terazono [187] followed a cargo container with 814 second-hand TVs traveling from Japan to the Philippines and found that 40 % of the TVs were in need of repair upon arrival, with 3% not making it through the journey at all. Other appliances, even if new, vary in quality depending on the price (a calculus that puts low-income residents in a difficult position). But still, most appliances have parts that are not made to last if voltage does surge. Surges degrade or damage even the best-quality ones. Voltage fluctuations are similarly problematic. Imagine with every fluctuating voltage the fluctuating current (think flows of electrons) makes its way through the conductors inside an appliance. The faster the flow, the more heat gets generated. This translates to metals physically getting hotter or cooler depending on the voltage – expanding and contracting as a result. Expand and contract long enough and they will "blow up."

"They pop!" she clapped her hands. A teacher at a rural primary school in the middle of the island, was talking about her light bulbs. Some last "lots of years," she thought. "This one (she points at a fluorescent light tube), they work for a long time. But those small ones don't...Maybe they will last for two months. Then pop. Some days you come home and they are dead." Six months was the average life of a light bulb according to most people I spoke with. In another home, one of the poorest homes I visited, with no TVs, fridges, couches, nor any living room furniture, the head of household said one month. "Just brought one home the other day, it burst in 2 days," she explained. Still, she bought them because kerosene was more expensive than paying the electric bill plus buying new bulbs.

4.5 Conclusion

When I began my fieldwork in Unguja in 2013, it had experienced decades of electricity access. Its history with electricity had not been incredibly long, but long enough for TVs and fridges to shift from uncommon appliances to omnipresent goods. Indeed, thirteen years after cultural anthropologist Tanja Winther began assessing the socio-cultural implications of newly electrified communities in a rural Zanzibari community, when she witnessed a

"reorganization of interior spaces" and everyday social life, I did not have many conversations with people "yearning for modernity" [178, 156]. Electricity had arrived to everyone but "the extremely poor." Engaging with people accustomed to these services and appliances, what has been the most striking is the non-binary nature of everyday connections: fluctuating voltages, intermittent outages, and, of course, the ever-present problem of cut-offs from unpaid electricity bills or "top-offs." Everyday connections are never quite steady.

Some of the stories found in these pages are not so new today. Anecdotes from the Global South on everyday life with unaffordable and unreliable electricity have been recounted in the past few years by many scholars especially works by Antina von Schnitzler, Sylvy Jaglin, Idalina Baptista, Michael Degani). In deliberately highlighting these stories and experiences as they more broadly relate to a global development discourse on electricity infrastructure, I argue there are divergent, if not at times incompatible, perspectives on what it means to be connected to electricity.

"Modern energy for all" rests on the assumption that electricity services will reshape people's relationship to biomass fuels while simultaneously creating opportunities for economic development. In this quest to electrify everyone and nearly everything, centralized grid systems have and will continue to play a pivotal role. These large socio-technical systems are embedded with past and present histories, and in sub-Saharan Africa, grid fragility and scarcity are linked to colonial and postcolonial relations. Yet the discourse on contemporary grid failures, utilities' insolvency, and dilapidated infrastructure, revolves heavily around the responsibility of residents: they do not pay enough, they do not consume enough, and what they do consume they do not pay for. In practice, accounting for these so-called problems – raising tariffs, changing payment regimes – may compound the difficulties people face in their already tenuous relationship with electricity.

Still, we are to understand that this type of access might be satisfactory, for a temporary (and undefined) period at least. The conviction that a "little goes a long way" or people can "cope" with unreliable and unaffordable access emerges from the very promises electricity offers up: that increasing connections of any sort (whether centralized or decentralized for that matter) will lead to "productive uses" – freeing up time for women, allowing children to study into the night – and decrease biomass pollutants in the homes.

Yet for Zanzibaris, these services are not so readily confined to such uses. Threatened by disconnections, possibilities of debt, or the inability to use electricity because there was not "enough power," people revealed to me the personal value they place on having such devices as lights, TVs, fans, rice cookers, and electric ovens for security, for fun, for comfort, for happiness. These desires are not so hard to understand; after all, people's needs and wants have multitudes, and certainly those invested in electricity for "human development" have expectations of electricity services that are not necessarily the same for those who are considered in need of development. What would it mean to construct a vision of electricity access for households that sees no clear path towards monetizing services, no children studying at night, no mothers with more "productive" time? What would it mean to construct a vision of electricity access that did not judge people's uses? To this end, who could affirm this vision had been realized and how? I am not saying that electricity services should not

be praised for what they can provide, but expectations must be tempered by the very fact that electricity for many is so unreliable and so unaffordable as to make the idea that any use of it is truly necessary inconceivable.

It is true, electricity carries important health benefits over biomass fuels. But "modern energy for all" as it is currently promoted, does not address the problem of (un)reliability, which reinforces households' reliance on dangerous biomass fuels jacome2018prepaid,jacome2019power. These prospects echo what I and others have recently observed in even the wealthiest communities. In the Bay Area this past December, highly unpopular power outages during the 2019 wildfire season saw many households purchasing generators (which run on biomass fuels) to stave off problems from relatively short interruptions. The lack of attention to level of access, fueled by value-laden assumptions, has huge implications for the very goals "modern energy for all" hopes to achieve. Similarly, broken appliances cost money and disadvantage the people purportedly helped by electricity access. A cheap, $50 fridge that breaks in a couple of months is not an easy loss for a person who averages $100 a month. Neither is a few $3 light bulbs breaking every few months. These are the conditions by which people are expected to cope and, in turn, find themselves bearing the burden – "the utility won't pay for a broken fridge" as one said. Such quiet forms of dispossession take a huge toll in homes throughout SSA.

Nevertheless, broken appliances, while upsetting for some, are so common-place they appear invisible for others. Over and over again, I witnessed a casual observation of a broken appliance here, a casual observation of a broken appliance there, without much protest. It took me exploring dark corners of houses and asking explicitly what appliances were or were not working in order to draw out the extent to which people *might be able* to benefit from access. The various shapes and forms intermittency took appeared to disorient people's perceptions.

> *Electricity goes out for three to four hours. Sometimes the entire day. Sometimes ten to eight hours of electricity. Don't know if there is even electricity right now. Is there electricity right now? Oh yes there is.*

This man's confusion over whether or not he had electricity at the moment, while we were sitting in a dark room together, reveals the extent to which broken-down infrastructure readily straddles a visible, invisible state in the context of (un)reliability. It also problematizes a conventional view of infrastructure – that its visibility only emerges when it breaks down, e.g. when bridges are washed away or when the power goes out [26], or when its becomes a barrier, e.g. a wheelchair is forced to traverse stairs [151]. Instead, I find that the invisibility of infrastructure in STS is predicated on the baseline expectation of continuous high quality services. Where unreliability is the norm like in Unguja, even a breakdown may become invisible because breakdowns are the rule rather than the exception. In contrast, we can understand the impacts of intermittency and the relationship of the user to the state in the Global North, when services break down in an emergency, as making the infrastructure "hyper" visible (following Star [151]). This paradox, the hyper-visibility of an otherwise invisible

infrastructure in a reliable regime, versus the near-invisibility of breakdowns in an unreliable regime, forces us to confront the way in which the visible-when-broken paradigm takes for granted the context of reliability.

"Living without electricity is difficult, because human beings need electricity. What would you want humans to do? They have to have electricity. But what you can't change you live with." This quote by an elderly woman encapsulates what I see is at stake in my last question: *What are the implications of taking expectations, or lack of them, seriously?* Electricity is important for Unguja residents. They value knowing they will not be "sleeping in the dark," they value being able to use appliances when they want, how they want. But they often cannot. The practice of living day-to-day under (un)reliability manifests as tempered expectations, with few claims made on their government, their utility, towards better services. Referring to what was perhaps a surprised look on my face when he told me there were often unannounced outages, one man said to me, "You are shocked but we are already used to it. We don't complain." So what politics does that leave us with? Do losses that potentially go unexpressed as a result carry less weight than those made forcefully over one or two days of no power in wealthier states? Are these invisible burdens less important? Is this what we are to expect of "modern energy for all"?

While disconnections caused by unaffordability versus intermittency may be felt differently and produce their own distinct politics, (un)reliability from any cause carries its quiet burdens. These burdens, however, remain largely invisible in the benevolent quest of "modern energy for all." The problem is that expectations are perhaps being met because expectations are so low. This is a type of national politics that allows global development politics to ignore the precarious vulnerabilities of unreliable services, in turn reinforcing the logic that "a little goes a long way." We might not be able to answer what level of access is mandated, but through observing people's everyday relationship to unreliable services, we can at least begin to recognize the disconnect between a global vision of access – what it is supposed to provide, how it is to be used – and the services that have come to be expected by those who use it.

Chapter 5

Conclusion

5.1 Towards a Relational Ontology of Postcolonial Infrastructure

> "The work of an intellectual is not to form the political will of others; it is, through the analyses he does in his own domains, to bring assumptions and things taken for granted again into question, to shake habits, ways of acting and thinking, to dispel the familiarity of the accepted. . . ."
>
> Michel Foucault

For this project, I have worked dialectically between a benchmark of cheap, stable, and readily available services and what is benchmarked against them: unaffordable, unstable, non-existent services. By first dichotomizing systems of service into abundant and constrained, I revealed contrasting socio-material conditions embedded in each system. Simply highlighting differences may problematically reinforce them, but importantly, I do not view these dichotomized systems as existing individually. Instead, I argue that neither of them can be rendered intelligible without the other.

If we are to ask why a system is so unreliable, we will only find our answer by asking: why is another system so reliable? I used this relational approach early on to pose a question central to my analysis: How could one imagine financing and sustaining electricity systems with anything other than full cost-recovery by residential users? The framing of this particular question grew out of Foucault's use of histories: they "aim to remove this air of necessity by showing that the past ordered things quite differently and that the processes leading to our present practices and institutions were by no means inevitable" [70, p 10]. In using history to inform the present, my objective was not to create a causal story by constructing a chronological series of events. Indeed, this type of historical account can be misleading. Instead, I have examined institutional arrangements across time and space to help bring to light viewpoints taken for granted and question the validity of present-day "knowledge."

A comprehensive understanding of postcolonial infrastructure requires a relational ontology. While this project falls short of a full "ontology," its relational approach is a stepping stone towards a more complete ontology of postcolonial infrastructure. By focusing my ethnographic lens mainly inside the residential household, and perhaps more accurately, the now-accustomed consumer of electricity, I began the project of contrasting the sub-Saharan African electricityscape with initiatives like "modern energy for all." I have shown the emergence of a distinct household electricityscape marked by persistent (un)reliability and the (sometimes) tempered expectations of Zanzibari residents. Some of these findings echo what others have found across urban Africa. Michael Degani describes a politics of electricity in Dar es Salaam and attendant infrastructural crises as creating the conditions by which "residents, technicians, and bureaucrats" allow themselves to continuously practice improvised forms of electricity access [156]. These forms of improvisations, together with an acceptance and management of everyday crises, has produced a truncated sense of infrastructural futures (ibid). Indeed, there is a timelessness to this type of unreliable and affordable electricity connection. The perception is that it is and will be this way. "Our electricity is not like yours," multiple Zanzibaris would tell me.

With this in mind, let us return to the question: How could one imagine financing and sustaining electricity systems with anything other than full cost-recovery by residential users? If you look at the history of Global North centralized grid systems, you will find a grid that did not rely on residential users for reliable and affordable connections. It appears they simply did not spread this way, instead they relied on large consummating industries (c.f. Bakke [14]). To imagine then that we can make sense of why African grids are so unreliable simply by looking at the faults of residential users or even more broadly, at the faults of politicians and technicians, is to ignore the possibility that Global North grids were never quite financially sustainable to begin with – and that reliability was perhaps detached from financial calculations altogether. But the stories we tell ourselves about the differences between unreliable and reliable electricity infrastructure, the prevailing sense of assumed and inevitable disparity, undermines the ability to create a new understanding of our collective global electricity futures.

5.2 The Upshot of an Interdisciplinary Study: From Institutions, to Electrons, to the Individual

In the matter of contemporary electricity development, "to bring assumptions and things taken for granted again into question," has required me to constantly go between analyzing and translating the technical to the social and vice versa. Seven years after I began this project, I now see it as part of a burgeoning scholarship which recognizes the need to perform the multi-disciplinary work of describing "the Grid" and its inner workings, lest a monumental infrastructure go unnoticed (for example [14]. Thus, in each chapter, I credit the importance of socio-material relations underpinning electricity access, while asking separate but related

questions regarding institutional practices, flows of electrons from substations to homes, and the everyday experiences that the grid mediates and is mediated by. Chapters 2 and 4 foreground the social aspects of (un)reliability, while chapter 3 focuses on the material. I do not take for granted that the difference between voltage fluctuations and extreme voltage fluctuations is materially consequential. Drops in voltage of twenty percent do not matter for the life of an appliance as much as drops of eighty percent. Accordingly, chapter 3 applies power systems monitoring to create a material account of unreliable services.

Still, this quantitative analysis cannot stand alone. Understanding the material consequences of extreme voltage fluctuations (for example) is to understand how people relate to the service when appliances break down. Furthermore, an inextricable component of the everyday, these important services also represent the inner workings of states and their economies. The other chapters are thus grounded in the social – chapter 2 leans towards a relational account of unaffordable and unreliable services between individuals, the service, and the utility; chapter 3 provides an ethnographic account from the vantage point of the individual user. Finally, all three chapters attempt to contextualize grid-systems in their complexities, so while I may lean on one mode of translation more heavily in a chapter, vignettes, historical references, and material descriptions permeate all three and the interconnections between chapters enhance the work as a whole. Taken together, they create a rich reflection on unreliable and affordable services, which counters presumptions of contemporary electricity development. All in all, this dissertation requires each of the three chapters to stretch the breadth and depth of an interdisciplinary approach that electricity studies demands.

5.3 Presumptions and Their Consequences

My project took its point of departure from a central premise, that contemporary electricity development carries with it three under-scrutinized assumptions – of goodness, of equity, and of abundance. I argue these assumptions work in and through one another to undermine the very project of "modern energy for all." I set myself the task of uncovering the resulting implications from three avenues of research: the production of everyday life in electricity systems that are not good or equitable; the evolution and fragmentation of authority and responsibility in the governance of electricity provision with the rise of the prepaid electric meter; using abundant grids of the Global North as benchmarks for modern energy services in the Global South. So what are the implications?

First, while highly unreliable and unaffordable electricity services produce particular subjectivities that shape the way people relate to their electricity services and the provider, these deprived services can become normalized and thus internalized by individuals and institutions writ large. Unreliable and unaffordable services condition people's expectations and demand, and as a result, quiet burdens and forms of dispossession may not be readily translated to the level of national and global politics.

Second, though the rise of the prepaid meter is seen as an efficient path to cost-recovery for

the benefit of the entire system and therefore all, it is not simply a new form of disconnection. Rather the prepaid meter fundamentally alters the terms of access: who provides credit and how, and whose responsibility it is to maintain everyday connections. This reshaping of relationships in the provision of electricity, which essentially casts the individual as a creditor while also placing responsibility on them to ensure lights are kept on in any given moment, cannot benefit all. Thus, the most vulnerable – the very all whom "modern energy for all" strives to include – will surely be discounted.

Last, but certainly not least, and importantly connected to the previous two, is the implication of benchmarking electricity services on abundant grid systems. The quest of "modern energy for all" would have us believe we can electrify all and everything. By fixating on some idealized end, we make possible erasing the histories of abundant grids: what it took to make them so cheap and so reliable. Indeed, if we were to examine what allowed advanced-industrialized economies to electrify all and everything, it would not take long before we recognized attendant exploitation and consequences of such a project. The spread of grid systems through processes tied to heavy-consuming industries in need of electricity or to outsized generation capacity in need of customers, has led to innumerable environmental problems. On the other hand, if we imagine electrifying all and everything through clean energy or through cost-recovery from low-consuming residential users, we spread constrained services.

Ultimately, the tensions at work in contemporary electricity development rest on one simple observation: when we prioritize one value, we inadvertently jeopardize another. An abundant benchmark as the vision for what we hope electricity to be also belies the fact that people are and have been living with services that are not modern. In the path to some end, these lived experiences still matter. It is not sufficient to rest on the benevolent aspirations of "modern energy for all." We must always evaluate and (re)evaluate what material conditions are being produced, where responsibilities and burdens are being placed, and who is set to benefit from one more connection. The answers here are not self-evident.

Bibliography

[1] Arun Agrawal. *Environmentality: Technologies of government and the making of subjects*. Duke University Press, 2005.

[2] Marian Aguiar. *Tracking modernity: India's railway and the culture of mobility*. University of Minnesota Press, 2011.

[3] Michaël Aklin et al. "Factors affecting household satisfaction with electricity supply in rural India". In: *Nature Energy* 1.11 (2016), p. 16170.

[4] Hunt Allcott, Allan Collard-Wexler, and Stephen D O'Connell. "How do electricity shortages affect industry? Evidence from India". In: *American Economic Review* 106.3 (2016), pp. 587–624.

[5] John Allen. "U.S. experts urge Trump to engage Africa". In: *allAfrica* (Nov. 2016). URL: `https://allafrica.com/stories/201611180070.html`.

[6] Trevor Serge Coleridge Alleyne and Mumtaz Hussain. *Energy subsidy reform in Sub-Saharan Africa: Experiences and lessons*. International Monetary Fund, 2013.

[7] Hachimenum Nyebuchi Amadi. "Impact of power outages on developing countries: Evidence from rural households in Niger Delta, Nigeria". In: *Journal of Energy Technologies and Policy* 5.3 (2015), pp. 27–38.

[8] Samir Amin and Brian Pearce. *Accumulation on a world scale: A critique of the theory of underdevelopment*. Vol. 2. Monthly Review Press New York, 1974.

[9] Thomas Barnebeck Andersen and Carl-Johan Dalgaard. "Power outages and economic growth in Africa". In: *Energy Economics* 38 (2013), pp. 19–23.

[10] N Angelou et al. *Global tracking framework*. Working Paper 77889 v.3. World Bank, 2013.

[11] Jean Arlet. *Electricity Tariffs, Power Outages and Firm Performance: A Comparative Analysis*. Tech. rep. http://pubdocs.worldbank.org/en/444681490076354657/Electricity-Tariffs-Power-Outages-and-Firm-Performance.pdf, Mar. 2017.

[12] Giovanni Arrighi, Nicole Aschoff, and Ben Scully. "Accumulation by dispossession and its limits: The Southern Africa paradigm revisited". In: *Studies in Comparative International Development* 45.4 (2010), pp. 410–438.

[13] Emmanuelle Auriol and Aymeric Blanc. "Capture and corruption in public utilities: The cases of water and electricity in Sub-Saharan Africa". In: *Utilities Policy* 17.2 (2009), pp. 203–216.

[14] Gretchen Bakke. *The Grid: The fraying wires between Americans and our energy future*. Bloomsbury Publishing, 2016.

[15] Sudeshna Banerjee et al. *Access, affordability, and alternatives: Modern infrastructure services in Africa*. MPRA Paper 27740. World Bank, 2008.

[16] Idalina Baptista. "'We Live on Estimates': Everyday Practices of Prepaid Electricity and the Urban Condition in Maputo, Mozambique". In: *International Journal of Urban and Regional Research* 39.5 (2015), pp. 1004–1019. DOI: 10.1111/1468-2427.12314.

[17] Thushyanthan Baskaran, Brian Min, and Yogesh Uppal. "Election cycles and electricity provision: Evidence from a quasi-experiment with Indian special elections". In: *Journal of Public Economics* 126 (2015), pp. 64–73.

[18] Asef Bayat. "Globalization and the politics of the informals in the Global South". In: *Urban informality: Transnational perspectives from the Middle East, Latin America, and South Asia* (2004).

[19] Bekele Bayissa. "A Review of the Ethiopian Energy Policy and Biofuels Strategy". In: *Digest of Ethiopia's national policies, strategies and programs, Addis Ababa: Forum for social studies*. 2008, pp. 209–237.

[20] Kate Bayliss, Terry McKinley, et al. "Privatising basic utilities in sub-Saharan Africa: The MDG impact". In: *Research Brief* 3 (2007).

[21] Mikul Bhatia and Niki Angelou. *Beyond connections: Energy access redefined*. World Bank, 2015.

[22] Wiebe E Bijker. *Of bicycles, bakelites, and bulbs: Toward a theory of sociotechnical change*. MIT press, 1997.

[23] Moussa P Blimpo and Malcom Cosgrove-Davies. *Electricity access in Sub-Saharan Africa : Uptake, reliability, and complementary factors for economic impact.* World Bank, 2019. URL: https://%5C%5Copenknowledge.worldbank.org/handle/10986/31333.

[24] Marc Bloch. "The historian's craft (New York, 1953)". In: *This is an English language translation of Bloch's Apologie pour I'histoire ou mPtier d'historien* (1941), pp. 1941–42.

[25] Austin H. Bonnett and Rob Boteler. *The impact that voltage variations have on AC induction motor performance*. https://aceee.org/files/proceedings/2001/data/papers/SS01_Panel2_Paper27.pdf. 2001.

[26] Geoffrey C Bowker and Susan Leigh Star. *Sorting things out*. Vol. 297. MIT Press, 1999.

[27] Cecilia Briceño-Garmendia and Maria Shkaratan. *Power tariffs: caught between cost recovery and affordability*. Policy Research Working Paper 5904. World Bank, 2011. URL: `https://ssrn.com/abstract=1970145`.

[28] Michael Burawoy. "The extended case method". In: *Sociological Theory* 16.1 (1998), pp. 4–33.

[29] Alfredo Burlando. "The impact of electricity on work and health: Evidence from a blackout in Zanzibar". In: *American Economic Association* (2010).

[30] Fiona Burlig and Louis Preonas. *Out of the darkness and into the light? Development effects of rural electrification*. Working Paper 268. Energy Institute at Haas, 2016.

[31] Catherine Casey. *Work, self, and society: After industrialism*. Psychology Press, 1995.

[32] Akanksha Chaurey and Tara Chandra Kandpal. "Assessment and evaluation of PV based decentralized rural electrification: An overview". In: *Renewable and Sustainable Energy Reviews* 14.8 (2010), pp. 2266–2278.

[33] International Electrotechnical Commission et al. "International standard–IEC 60038". In: *IEC* (2002).

[34] Paul Cook. "Infrastructure, rural electrification and development". In: *Energy for Sustainable Development* 15.3 (2011), pp. 304–313.

[35] Stuart Corbridge et al. *Seeing the state: Governance and governmentality in India*. Vol. 10. Cambridge University Press, 2005.

[36] Council of European Energy Regulators. *CEER Benchmarking Report 6.1 on the Continuity of Electricity and Gas Supply*. Tech. rep. https://www.ceer.eu/documents/104400/-/-/963153e6-2f42-78eb-22a4-06f1552dd34c, July 2018.

[37] Anton Eberhard et al. *Underpowered: The state of the power sector in Sub-Saharan Africa*. Background Paper 6. World Bank, 2008.

[38] Emmanuel Effah and Kingsley Bediako Owusu. "Evolution and efficiencies of energy metering technologies in Ghana". In: *Global Journal of Research In Engineering* 14.6 (2014).

[39] Sean Elphick et al. "Voltage sag susceptibility of 230 V equipment". In: *IET Generation, Transmission & Distribution* 7.6 (2013), pp. 576–583.

[40] Alexander Eigeles Emanuel and and John A McNeill. "Electric power quality". In: *Annual review of energy and the environment* 22.1 (1997), pp. 263–303.

[41] Antonio Estache. *Infrastructure and development: A survey of recent and upcoming issues*. Working Paper 71340. World Bank, 2007.

[42] Samuel Fankhauser and Sladjana Tepic. "Can poor consumers pay for energy and water? An affordability analysis for transition countries". In: *Energy Policy* 35.2 (2007), pp. 1038–1049.

[43] Andrew Feenberg. *Transforming technology: A critical theory revisited*. Oxford University Press, 2002.

[44] James Ferguson. "The uses of neoliberalism". In: *Antipode* 41 (2010), pp. 166–184.

[45] Harald Fischer-Tiné and Michael Mann. *Colonialism as civilizing mission: Cultural ideology in British India*. Anthem Press, 2004.

[46] Vivien Foster and Cecilia Briceño-Garmendia. *Africa's infrastructure: a time for transformation*. The World Bank, 2010.

[47] Vivien Foster and Jevgenijs Steinbuks. *Paying the price for unreliable power supplies: In-house generation of electricity by firms in Africa*. Policy Research Working Paper 4913. World Bank, 2009.

[48] Michel Foucault. "Discipline and Punish, trans". In: *Alan Sheridan (New York: Vintage, 1979)* 191 (1977).

[49] Michel Foucault. *The archaeology of knowledge: Translated from the french by AM Sheridan Smith*. Pantheon Books, 1972.

[50] M Foucault et al. "Security, territory, population: lectures at the Collège de France, 1977-78". In: (2007).

[51] Andre Gunder Frank. *The development of underdevelopment*. New England Free Press, 1969.

[52] Thomas Frost and P Mitcheson. *Impact of wider voltage tolerances on consumer electronics and wider socialised costs*. Report. Imperial College London, 2013.

[53] Duncan G Fullerton, Nigel Bruce, and Stephen B Gordon. "Indoor air pollution from biomass fuel smoke is a major health concern in the developing world". In: *Transactions of the Royal Society of Tropical Medicine and Hygiene* 102.9 (2008), pp. 843–851.

[54] Rebecca Ghanadan. "Connected geographies and struggles over access: Electricity commercialisation in Tanzania". In: *Electric Capitalism. Recolonising Africa on the Power Grid* (2009).

[55] Rebecca Hansing Ghanadan. *Public service or commodity goods? Electricity reforms, access, and the politics of development in Tanzania*. PhD thesis. University of California, Berkeley, 2008.

[56] Barney G Glaser and Anselm L Strauss. "The constant comparative method of qualitative analysis". In: *The discovery of grounded theory: Strategies for qualitative research* 101 (1967).

[57] Barney Glaser and Anselm Strauss. "The discovery of grounded theory. 1967". In: *Weidenfield & Nicolson, London* (1967), pp. 1–19.

[58] Edgard Gnansounou et al. "Strategies for regional integration of electricity supply in West Africa". In: *Energy Policy* 35.8 (2007), pp. 4142–4153.

[59] Google Maps. *The United Republic of Tanzania*. 2017. URL: https://www.google.com/maps/place/Tanzania/@-6.1021661,34.1716811,7z/data=!4m5!3m4!1s0x184b51314869a111:0x885a17314bc1c430!8m2!3d-6.369028!4d34.888822?hl=en.

[60] Google Maps. *The United Republic of Tanzania*. https://www.google.com/maps/place/Tanzania/@-6.1021661,34.1716811,7z/data=!4m5!3m4!1s0x184b51314869a111:0x885a17314bc1c430!8m2!3d-6.369028!4d34.888822?hl=en.. 2017.

[61] Government of Tanzania. *Revisited Zanzibar Development Vision 2020*. Working Document. The United Republic of Tanzania, Oct. 2011. URL: http://mipangoznz.go.tz/wp-content/uploads/2015/01/Revisited%7B%5C_%7DZanzibar%7B%5C_%7DVision%7B%5C_%7D2020.

[62] Government of Zanzibar. *Revisited Zanzibar Development Vision 2020*. http://mipangoznz.go.tz/wp-content/uploads/2015/01/RevisitedZanzibarVision2020. October, 2011.

[63] Government of Zanzibar. *Zanzibar household budget survey 2014 2015*. Office of the Chief Government Statistician, 2015.

[64] Stephen Graham and Simon Marvin. *Splintering urbanism: networked infrastructures, technological mobilities and the urban condition*. Psychology Press, 2001.

[65] Francisco Javier Arze del Granado, David Coady, and Robert Gillingham. "The unequal benefits of fuel subsidies: A review of evidence for developing countries". In: *World Development* 40.11 (2012), pp. 2234–2248.

[66] Mark Granovetter. "Economic action and social structure: The problem of embeddedness". In: *American Journal of Sociology* 91.3 (1985), pp. 481–510.

[67] Michael Grimm et al. *A first step up the energy ladder?* Working Paper 7859. World Bank, 2016.

[68] Akhil Gupta. "An anthropology of electricity from the global south". In: *Cultural Anthropology* 30.4 (2015), pp. 555–568.

[69] Daniel Gurara et al. *Trends and challenges in infrastructure investment in low-income developing countries*. International Monetary Fund, 2017.

[70] Gary Gutting et al. *The Cambridge Companion to Foucault*. Cambridge University Press, 2005.

[71] Jonathan Halpern, Charles Kenny, and Eric; Dickson. *Deterring corruption and improving governance in the electricity sector*. World Bank, 2008.

[72] TJ Hammons et al. "African electricity infrastructure interconnections and electricity exchanges". In: *IEEE Transactions on Energy Conversion* 15.4 (2000), pp. 470–480.

[73] Denzel Hankinson et al. *Tanzania energy sector impact evaluation: Findings from the Zanzibar baseline study*. Report. Mathematica Policy Research, Inc., 2011.

[74] Clive Harris. *Private participation in infrastructure in developing countries: Trends, impacts, and policy lessons*. Working Paper 5. World Bank, 2003.

[75] David Harvey. *Spaces of global capitalism*. Verso, 2006.

[76] Friedrich A Hayek. *The road to serfdom*. Chicago University Press, 1944.

[77] V Henze and U Janette. "Price and need for reliable electricity power are spurring solar sales to African businesses ". In: *BloombergNEF* (Jan. 2019). URL: https://about.bnef.com/blog/price-need-reliable-electricity-power-spurring-solar-sales-african-businesses/.

[78] Peter van Heusden. "Discipline and the 'new logic of delivery': Prepaid electricity in South Africa and beyond". In: *Electric capitalism: Recolonising Africa on the power grid* (2012).

[79] Richard F Hirsh. *Power loss: The origins of deregulation and restructuring in the American electric utility system*. MIT Press, 1999.

[80] P Hughes Thomas. "The evolution of Large Technical Systems". In: *The social construction of technological systems. New directions in the sociology and history of technology* (1989).

[81] Thomas P Hughes. *Networks of power: Electric supply systems in the US, England and Germany, 1880-1930*. Johns Hopkins University Press, 1983.

[82] Tim Ingold. *Anthropology: Why it matters*. John Wiley & Sons, 2018.

[83] Mwaka Ismail, Min-You Chen, and Xia Li. "Optimal planning for power distribution network with distributed generation in Zanzibar Island". In: *2011 International Conference on Electrical and Control Engineering*. IEEE. 2011, pp. 266–269.

[84] Y Issa. "Tanzania: Zanzibar utility firm queries TANESCO's over Sh70 billion debt". In: *Daily News* (Jan. 2014).

[85] B Kelsey Jack and Grant Smith. *Charging ahead: Prepaid electricity metering in South Africa*. Tech. rep. National Bureau of Economic Research, 2016.

[86] Veronica Jacome and Isha Ray. "The prepaid electric meter: Rights, relationships and reification in Unguja, Tanzania". In: *World Development* 105 (2018), pp. 262–272.

[87] Veronica Jacome et al. "Power quality and modern energy for all". In: *Proceedings of the National Academy of Sciences* 116.33 (2019), pp. 16308–16313.

[88] Sylvy Jaglin. "Differentiating networked services in Cape Town: Echoes of splintering urbanism?" In: *Geoforum* 39.6 (2008), pp. 1897–1906. DOI: 10.1016/j.geoforum.2008.04.010. URL: http://dx.doi.org/10.1016/j.geoforum.2008.04.010.

[89] Sylvy Jaglin and Alain Dubresson. *Eskom. Electricity and Technopolitics in South Africa*. UCT Press, 2016.

[90] Yunfen Ji, Robert Davis, and Weihong Chen. "An investigation of the effect of operating cycles on the life of compact fluorescent lamps". In: *Journal of the Illuminating Engineering Society* 28.2 (1999), pp. 57–62.

[91] Timo Jütten. "What is reification? A critique of Axel Honneth". In: *Inquiry* 53.3 (2010), pp. 235–256.

[92] Nyasha Kaseke and Stephen G Hosking. "Sub-Saharan Africa electricity supply inadequacy: Implications". In: *Eastern Africa Social Science Research Review* 29.2 (2013), pp. 113–132.

[93] Eliel Keelson, K.O. Boateng, and Isaac Ghansah. "Low cost early adoption procedures for implementing smart prepaid metering systems in African developing countries". In: *Journal of Multidisciplinary Engineering, Science and Technology* 2.2 (2015), pp. 240–250.

[94] Kevin J Kelley. "Obama's legacy projects in Africa may be targeted by Trump ". In: *allAfrica* (Nov. 2016). URL: `https://allafrica.com/stories/201611180194.html`.

[95] Francis Kemausuor and Emmanuel Ackom. "Toward universal electrification in Ghana". In: *Wiley Interdisciplinary Reviews: Energy and Environment* 6.1 (2017).

[96] John Maynard Keynes. *The general theory of employment, interest, and money*. Springer, 1936.

[97] Masami Kojima, Robert Bacon, and Chris Trimble. *Political economy of power sector subsidies: A review with reference to Sub-Saharan Africa*. Working Paper 89547. World Bank, 2014.

[98] Masami Kojima and Chris Trimble. *Making Power Affordable For Africa and Viable for Its Utilities*. Report. World Bank, 2016. URL: `http://hdl.handle.net/10986/25091`.

[99] Bryan Bonsuk Koo et al. *Rwanda–Beyond Connections: Energy Access Diagnostic Report Based on the Multi-Tier Framework*. World Bank, 2018.

[100] Julian A Lampietti, Sudeshna Ghosh Banerjee, and Amelia Branczik. *People and power: Electricity sector reforms and the poor in Europe and Central Asia*. World Bank, 2007.

[101] Kenneth Lee, Edward Miguel, and Catherine Wolfram. *Electrification and economic development: A microeconomic perspective*. Tech. rep. Oxford Policy Management, 2017.

[102] Luciane Lenz et al. "Does large-scale infrastructure investment alleviate poverty? Impacts of Rwanda's electricity access roll-out program". In: *World Development* 89 (2017), pp. 88–110.

[103] Les Levidow. "Democratizing technology–or technologizing democracy? Regulating agricultural biotechnology in Europe". In: *Technology in Society* 20.2 (1998), pp. 211–226.

[104] Tania Murray Li. "Governmentality". In: *Anthropologica* 49.2 (2007), pp. 275–281.

[105] Alex Loftus. *Everyday environmentalism: Creating an urban political ecology*. University of Minnesota Press, 2012.

[106] Alex Loftus. "Reification and the dictatorship of the water meter". In: *Antipode* 38.5 (2006), pp. 1023–1045.

[107] Georg Lukács. *History and class consciousness: Studies in Marxist dialectics*. Vol. 215. MIT Press, 1971.

[108] Albert Malama et al. "The Effects of the Introduction of Prepayment Meters on the Energy Usage Behaviour of Different Housing Consumer Groups in Kitwe, Zambia". In: *AIMS Energy* 2.3 (2014), pp. 237–259.

[109] Karl Marx. *Capital, volume I*. 1867.

[110] Karl Marx and Friedrich Engels. *The communist manifesto*. Penguin, 1847 [2000].

[111] Othman Maulid. "Kutoka Baraza la Wawakilishi Zanzibar. [From the House of Representatives Zanzibar.]" In: *ZanziNews* (July 2015). URL: www.zanzinews.com/2015/06/kutoka-baraza-la-wawakilishi-zanzibar.html.

[112] P T Mburu and C R Sathyamoorthi. "Switching from post-paid to pre-paid models: customer perception and the organisational role in managing the change: A case study of Botswana Power Corporation". In: *Journal of Management Research* 6.3 (2014), p. 175.

[113] Bill McKibben. "Power brokers: Africa's solar boom is changing life beyond the grid". In: *The New Yorker* (June 2017), pp. 46–55.

[114] Monga Mehlwana. *The economics of energy for the poor: Fuel and appliance purchase in low-income urban households*. ERDC Report Series. University of Cape Town, 1999.

[115] Faranak Miraftab and Shana Wills. "Insurgency and spaces of active citizenship the Story of western cape anti-eviction campaign in South Africa". In: *Journal of Planning Education and Research* 25.2 (2005), pp. 200–217.

[116] Timothy Mitchell. *Rule of experts: Egypt, techno-politics, modernity*. Univ of California Press, 2002.

[117] Carolyne Nyanchama Miyogo, Steve Ondieki Nyanamba, and Gaster Nashappi Nyangweso. "An Assessment of the Effect of Prepaid Service Transition in Electricity Bill Payment on KP Customers, a Survey of Kenya Power, West Kenya Kisumu". In: *American International Journal of Contemporary Research* 3.9 (2013), pp. 88–96.

[118] A Mtulya. "Magufuli directs Tanesco to cut power supply to Zanzibar over debt." In: *The East African* (Mar. 2017). URL: http://www.%20theeastafrican.co.ke/news/Cut-power-to-Zanzibar-Magufuli-tells-Tanesco/%202558-3839366-5iqswwz/index.html.

[119] Francis M Mwaura. "Adopting electricity prepayment billing system to reduce non-technical energy losses in Uganda: Lesson from Rwanda". In: *Utilities Policy* 23 (2012), pp. 72–79.

[120] NBS. *2012 Population and Housing Census*. 2013.

[121] Innocent Chidi Nnorom and Oladele Osibanjo. "Electronic waste (e-waste): Material flows and management practices in Nigeria". In: *Waste Management* 28.8 (2008), pp. 1472–1479.

[122] Nordic Consulting Group. *End-review of phase IV and extension of the Zanzibar rural electrification project: Final report April 2009*. Tech. rep. Nordic Consulting Group, Apr. 2009.

[123] Northeast Group. *Sub-Saharan Africa electricity metering: Market forecast (2014 to 2024)*. Report. Northeast Group, LLC, 2014.

[124] MR Nouni, SC Mullick, and TC Kandpal. "Providing electricity access to remote areas in India: An approach towards identifying potential areas for decentralized electricity supply". In: *Renewable and Sustainable Energy Reviews* 12.5 (2008), pp. 1187–1220.

[125] Office of the Chief Government Statistician Zanzibar. *Zanzibar socio - economic survey 2014: Preliminary statistical report*. Office of the Chief Government Statistician Zanzibar, May 2015.

[126] Ronald Ontomwa. "Effect of prepaid electricity billing on revenue collection costs at Kenya power company". PhD thesis. University of Nairobi, 2014.

[127] OPHI. *OPHI Country Briefing 2013: Tanzania*. 2013. URL: `http://www.ophi.org.uk/wp-content/uploads/Tanzania-2013.pdf`.

[128] James E Payne. "Survey of the international evidence on the causal relationship between energy consumption and growth". In: *Journal of Economic Studies* (2010).

[129] Gajo Petrovíc. *A dictionary of Marxist thought*. 1983.

[130] Marie Plancq-Tournadre. "Services d'eau et d'électricité au Cap, ou comment la sortie de l'apartheid fabrique des débranchés". In: *Flux* 2 (2004), pp. 13–26.

[131] Patrick Plane. "Privatization, technical efficiency and welfare consequences: the case of the Côte d'Ivoire electricity company (CIE)". In: *World Development* 27.2 (1999), pp. 343–360.

[132] Karl Polyani. "The great transformation". In: *New York: Rinehart* (1944), pp. 209–227.

[133] PSL. *Power Standards Lab*. `https://www.powerstandards.com`. 2019.

[134] Ana Pueyo and Mar Maestre. "Linking energy access, gender and poverty: A review of the literature on productive uses of energy". In: *Energy Research & Social Science* 53 (2019), pp. 170–181.

[135] John Quayson-Dadzie. "Customer perception and acceptability on the use of prepaid metering system in Accra West Region of Electricity Company of Ghana". PhD thesis. Institute Of Distance Learning, Kwame Nkrumah University of Science and Technology, 2012.

[136] S Raphelson. "U.S. utilities look to electric cars as their savior amid decline in demand". In: *NPR* (Mar. 2018).

[137] Orvika Rosnes and Maria Shkaratan. *Africa's power infrastructure: Investment, integration, efficiency*. World Bank, 2011.

[138] Orvika Rosnes and Haakon Vennemo. "The cost of providing electricity to Africa". In: *Energy Economics* 34.5 (2012), pp. 1318–1328.

[139] Walt W Rostow. *The stages of growth: A non-communist manifesto*. Cambridge University Press, 1960.

[140] Emma Rothschild. "Adam Smith and conservative economics". In: *Economic History Review* (1992), pp. 74–96.

[141] Greg Ruiters. "Contradictions in municipal services in contemporary South Africa: Disciplinary commodification and self-disconnections". In: *Critical Social Policy* 27.4 (2007), pp. 487–508.

[142] Ambuj D Sagar. "Alleviating energy poverty for the world's poor". In: *Energy Policy* 33.11 (2005), pp. 1367–1372.

[143] Sahel Standards News. "Prepaid metering to attract 11.4 billion investment in 10 years". In: *Sahel Standards News* (July 2016). URL: http://sahelstandard.com/index.php/2016/07/06/prepaid-metering-to-attract-11-4-billion-%20investment-in-10years/.

[144] Aly Sanoh et al. "The economics of clean energy resource development and grid interconnection in Africa". In: *Renewable Energy* 62 (2014), pp. 598–609.

[145] Antina Schnitzler. "Traveling technologies: Infrastructure, ethical regimes, and the materiality of politics in South Africa". In: *Cultural Anthropology* 28.4 (2013), pp. 670–693.

[146] James C Scott. *Seeing like a state: How certain schemes to improve the human condition have failed*. Yale University Press, 1998.

[147] Hussain Shareef, Azah Mohamed, and Khodijah Mohamed. "Sensitivity of compact fluorescent lamps during voltage sags: An experimental investigation". In: *WSEAS Transactions on Power Systems* 1.5 (2010), pp. 22–31.

[148] Jonathan Silver. "Disrupted infrastructures: An urban political ecology of interrupted electricity in Accra". In: *International Journal of Urban and Regional Research* (2016).

[149] Kirk R Smith. "Indoor air pollution in developing countries: Recommendations for research". In: *Indoor Air* 12.3 (2002), pp. 198–207.

[150] Neil Smith. "Uneven Development: Nature". In: *Capital, and the Production of Space* 3 (1984).

[151] Susan Leigh Star. "The ethnography of infrastructure". In: *American Behavioral Scientist* 43.3 (1999), pp. 377–391.

[152] Philip Sterchele, Andreas Palzer, and Hans-Martin Henning. "Electrify everything?: Exploring the role of the electric sector in a bearly CO2-neutral national energy system". In: *IEEE Power and Energy Magazine* 16.4 (2018), pp. 24–33.

[153] J Stottlemyer. "What we mean by 'productive use'—and why it matters". In: *Power For All* (Oct. 2018). URL: https://www.powerforall.org/insights/dre-technologies/what-we-mean-productive-use-and-why-it-matters.

[154] Anselm Strauss and Juliet Corbin. *Strauss, A., & Corbin, J. (1990).* Vol. 3. 1990, p. 379. ISBN: 0803959400. DOI: 10.4135/9781452230153.

[155] Anselm Strauss and Juliet M Corbin. *Grounded theory in practice*. Sage, 1997.

[156] Sarah Strauss, Stephanie Rupp, and Thomas Love. "Powerlines: cultures of energy in the twenty-first century". In: *Cultures of Energy: Power, Practices and Technologies* (2013), pp. 10–38.

[157] Erik Swyngedouw et al. *Power, water and money: exploring the nexus*. Tech. rep. Human Development Report Office (HDRO), United Nations Development Programme . . ., 2006.

[158] Devi Datt Tewari and Tushaar Shah. "An assessment of South African prepaid electricity experiment, lessons learned, and their policy implications for developing countries". In: *Energy Policy* 31.9 (2003), pp. 911–927.

[159] The Daily Nation. *Zanzibar starts settling power debt after Magufuli directive*. 2017. URL: http://www.nation.co.ke/business/Zanzibar-govt-starts-settling-Tanesco-debt--minister-says/996-3856776-xlklq6z/.

[160] The Economist. "Ending energy poverty power to the powerless". In: *Economist* (Feb. 2016). URL: https://www.economist.com/news/international/21693581-new-electricity-system-emerging-bring-light-worlds-poorest-key.

[161] The Guardian. "ZECO officials in illegal power scam". In: *The Guardian* (Jan. 2013). URL: http://www.ippmedia.com/fronted/funcations/print%7B%5C_%7Darticle.php?%7B%5C%%7D7C=50600.

[162] K Tijdens, J Besamusca, G Kahyarara, et al. *Wages in Zanzibar: Wageindicator survey 2013*. Tech. rep. 2014.

[163] Stephen Edelston Toulmin. *The return to cosmology: Postmodern science and the theology of nature*. University of California Press, 1982.

[164] Christopher Philip Trimble et al. *Financial viability of electricity sectors in Sub-Saharan Africa: Quasi-fiscal deficits and hidden costs*. Policy Research Working Paper 7788. World Bank, 2016. URL: https://ssrn.com/abstract=2836535.

[165] Ulrika Trovalla and Eric Trovalla. "Infrastructure turned suprastructure: Unpredictable materialities and visions of a Nigerian nation". In: *Journal of Material Culture* 20.1 (2015), pp. 43–57.

[166] Gordon Tullock. *The politics of bureaucracy*. Public Affairs, 1965.

[167] Stephen Tully. "The human right to access electricity". In: *Electricity Journal* 19.3 (2006), pp. 30–39. DOI: 10.1016/j.tej.2006.02.003.

[168] United Nations. "Transforming our world: The 2030 agenda for sustainable development". In: *General Assembley 70 session* 16301.October (2015), pp. 1–35. DOI: 10.1007/s13398-014-0173-7.2. arXiv: arXiv:1011.1669v3.

[169] Jonas Van der Straeten and Ute Hasenöhrl. "Connecting the Empire: New research perspectives on infrastructures and the environment in the (post) colonial world". In: *NTM Zeitschrift für Geschichte der Wissenschaften, Technik und Medizin* 24.4 (2016), pp. 355–391.

[170] Antina von Schnitzler. "Citizenship prepaid: Water, calculability, and techno-politics in South Africa". In: *Journal of Southern African Studies* 34.4 (2008), pp. 899–917.

[171] Njeri Wamukonya. "Power sector reform in developing countries: Mismatched agendas". In: *Energy Policy* 31.12 (2003), pp. 1273–1289.

[172] Paul Warmington. "Taking race out of scare quotes: Race-conscious social analysis in an ostensibly post-racial world." In: *Race, Ethnicity & Education* 12.3 (2009), pp. 281–296. DOI: 10.1080/13613320903178253.

[173] Max Weber. *On the methodology of the social sciences*. Free Press, 1949.

[174] Richard White. *The organic machine: The remaking of the Columbia River*. Macmillan, 1996.

[175] James H Williams and Rebecca Ghanadan. "Electricity reform in developing and transition countries: A reappraisal". In: *Energy* 31.6 (2006), pp. 815–844.

[176] Harald Winkler et al. "Access and affordability of electricity in developing countries". In: *World Development* 39.6 (2011), pp. 1037–1050.

[177] Tanja Winther. "Electricity theft as a relational issue: A comparative look at Zanzibar, Tanzania, and the Sunderban Islands, India". In: *Energy for Sustainable Development* 16.1 (2012), pp. 111–119. DOI: 10.1016/j.esd.2011.11.002.

[178] Tanja Winther. *The impact of electricity: Development, desires and dilemmas*. Berghahn Books, 2013.

[179] World Bank Group. *Ghana - Energy sector transformation initiative project*. Tech. rep. 2018. URL: http://documents.worldbank.org/curated/en/953141527091798128/pdf/Project-Information-Document-Integrated-Safeguards-Data-Sheet-Ghana-Energy-Sector-Transformation-Initiative-Project-P163984.pdf.

[180] World Bank Group. *Implementation completion report (ICR) review - Tz-power vi*. Tech. rep. Independent Evaluation Group, 2003. URL: http://lnweb90.worldbank.org/oed/oeddoclib.nsf/DocUNIDViewForJavaSearch/8525682E0068603785256D55%5C%5C004FDFA3?OpenDocument.

[181] World Bank Group. *Implementation completion report on a credit in the amount of 200 million usd equivalent to the United Republic of Tanzania for Tanzania power vi project*. Tech. rep. 26745. Energy Team Africa Region, June 2003. URL: http://documents.worldbank.org/curated/en/264191468760799364/pdf/267450icr.pdf.

[182] World Bank Group. *International Development Association Project Paper On A Proposed Additional Credit In the Amount of Euro 62.8 Million To The Republic of Senegal For the Electricity Sector Support Project*. Tech. rep. PAD1815. World Bank, July 2016.

[183] World Bank Group. *Project information document (PID) Appraisal stage: Gambia*. Tech. rep. PIDA27610. World Bank, DC., 2016.

[184] World Bank Group. *State of Electricity Access Report*. Tech. rep. https://openknowledge.worldbank.org/handle/10986/26646: World Bank, 2017.

[185] World Bank Group. *State of electricity access report 2017 (Vol. 2)*. Tech. rep. The World Bank, 2017. URL: http://documents.worldbank.org/curated/en/364571494%5C517675149/full-report.

[186] Grace C Wu et al. "Strategic siting and regional grid interconnections key to low-carbon futures in African countries". In: *Proceedings of the National Academy of Sciences* 114.15 (2017), E3004–E3012.

[187] Aya Yoshida and Atsushi Terazono. "Reuse of secondhand TVs exported from Japan to the Philippines". In: *Waste Management* 30.6 (2010), pp. 1063–1072.

[188] Issa Yussuf. *All villages to have power by 2020*. Online. June 2016. URL: http://www.dailynews.co.tz/index.php/home-news/51176-all-villages-to-have-power-by-2020.

[189] Issa Yussuf. *isles owes billions in power bills*. Dec. 2015. URL: http://dailynews.co.tz/index.php/home-news/45146-isles-owes-billions-in-power-bills.

[190] Zanzibar Assembly's Thirteenth Meeting on July 9th, 2009. In: 91 (July 2009). URL: http://zanzibarassembly.go.tz/Hansard/2009/bg-july/kikao-cha-kumi-na-tatu.pdf.

Appendix A

For Chapter 2

(a) Top-tier house

(b) Middle-tier house

Figure A.1: Typical Appliances in Top- and Bottom-Tier Households

One single lightbulb hangs on the left-side wall.

Figure A.2: Typical Appliances in Bottom-Tier Households

Table A.1: Characteristics of Sample Population

Subject	Participanting Households by Tier Group (N=51)		
	Top	Middle	Bottom
Sex			
Female	7	10	4
Male	3	22	10
Age of Participant, yrs			
18-29	2	2	1
30- 49	6	13	6
50-69	2	12	7
$\geq$ 70	0	5	1
Size of Household, avg., sd (%)	3.3 , 1.8	5.7, 2.6	4.3, 1.8
Declared Employment Type			
Employed for wages	3	10	4
Self-employed: business owner	5	4	0
Self-employed	1	7	5
Retired	0	1	0
Undeclared	3	3	3
Households w/:			
Motorized Vehicles, (%)	.4	.1	0
Immovable Furniture, (%)	1	.9	.2

Appendix B

For Chapter 3

Having a range of interview types and interviewees ensured that we captured a wide set of experiences and perceptions related to electricity access on the island. Thus, interviewees were purposively selected for broad representation. We identified participants from a variety of locations - regionally and within local communities - interviewing some households far from local roads, closer or farther to local transformers, those in apartment buildings, shared spaces, or single family homes. We identified wealthier residents and poorer residents by the types of homes (e.g. materials and structural stability) and types of neighborhoods (infrastructure build-up, density, closeness to markets, and businesses). Once inside the home, we took note of immovable furniture and other more expensive assets, and asked basic socio-economic related questions, to assess socioeconomic status. This range of interview selection and documentation of experiences led to saturation on key themes and informed our survey instrument.

We conducted surveys in sites A and B. The two sites were chosen because they have similar socioeconomic and geographical characteristics, and are located on different parts of the Unguja grid. Grid independence was important as it allowed for a robust set of results: a failure at one feeder level could not dominate the results. Furthermore, both sites can be considered peri-urban, neither part of the main urban hub on the island, nor strictly isolated (each site has a designated bus line, and is roughly equidistant to the nearest urban hub). Table B.2 shows household and participant characteristics for each site. The participating households were classified into top, middle, and bottom thirds to represent socioeconomic levels. Each site contained roughly the same number of top-, middle-, and bottom-tier households. We placed households in these tiers by following the methods in Jacome and Ray (2018), incorporating education levels, job type and status, and household assets and building materials [86]. For a more thorough discussion please see page 267 in [86]. We note that because all our participants were connected to the main electric grid, even our low-tier group is not the poorest of the Zanzibari community; thus our groups are not representative of the lowest socioeconomic status on the island.

The survey instrument served as our source of information on the electricity and voltage problems, including the most severe ones, experienced by households. The full range of

possible problems that respondents chose from was: not enough hours of electricity; low voltage problems; unpredictable interruptions; unexpectedly high bills; too expensive; do not trust the utility; power is not sufficient for the appliances I use; maintenance or service problems; unpredictable bills; no problems; other.

In Table B.6 we compare all household and participant characteristics (for both sites A and B combined) to all of Zanzibar. All of Zanzibar statistics (under Zanzibar Total in the last column of Table B.6) come from the 2014-2015 Household Budget Survey (HBS) [63]. Our participants were found to be representative of Zanzibari residents, if not faring slightly better on most socioeconomic metrics, such as education, asset ownership, and employment. (Unemployment was higher in our sample because we incorporated working at home in this figure, while HBS separated it.) This representation is to be expected since HBS did not subset by those connected to the grid. Furthermore, because of this sampling difference, electricity appliance ownership data in HBS was much lower than ours. For example, 76 percent of households in our sample owned a TV, while HBS found just 53.3 percent. Therefore, we did not include Zanzibar Total information for electrical appliances. Nevertheless, our sample's appliance ownership figures are comparable to figures found in [86]. Other statistics were not easily comparable, including age dependency ratio, and total employed and unemployed. HBS calculated the age dependency ratio as the number of people under 15 and over 64 divided by those between 15 and 64, while we calculated it as those under 18 and over 70 divided by those between 18 and 70. For employment, HBS included those that worked from home (roughly 22% of the population), while we did not specify. We believe lack of specificity is reflected in our higher unemployment rate. Lastly, HBS shows household ownership of many goods decreasing, sometimes drastically, from the 2009/2010 survey to the 2014/2015 survey. For example, in 2009/2010 53.9 percent of households owned a bicycle, while in 2014/2015 only 33.9 percent did. The 2014-2015 HBS report concludes that ownership of goods found in their survey is not always a reliable indicator of socioeconomic status, leading the authors of this paper to question the value of comparing some of these ownership figures.

For our power systems analysis, we assigned a per unit (PU) voltage to participating survey households based on the PU mean and first quartile (Q1) voltage measured at the closest sensor. PU mean was rounded up if the voltage captured at a sensor fell within the +/- 10% range - deemed acceptable by ZECO - for 90% of the time (or if the Q1 voltage was within the +/- 10% range). Otherwise, we rounded to the nearest .5 Volt. This choice in PU aggregation takes into account the range of voltage fluctuation at each sensor and the allowable voltage range set by ZECO.

Table B.1: Household and Participant Characteristics For Site A and B

Subject Participants by Site	Site A	Site B
# of Households	76	75
# of Participants (>18 yrs)	222	183
Size of Household, avg.	5.6	5.5
# of Top-Tier Households	21	26
# of Middle-Tier Households	26	26
# of Bottom-Tier Households	29	23
Employment Type (%)		
Employed	54.5	55.2
Unemployed	32.88	24.04
Student	6.3	3.28
Head of Household		
Highest Education Level		
Primary I or II	30.6	30.2
Secondary I or II	51.4	41.3
University	2.8	3.2
No Formal Education (%)	15.3	24.2

Table B.2: Household Assets For Site A and B

Subject Participants by Site	Site A	Site B
# of Households	76	75
Households Assets (%):		
Fridge	30.3	24.2
Freezer	26.3	26.7
TV	79	74.7
Sofa Couch	19.7	12
Motorcycle	13.2	13.3
Car	13.2	10.7
Bicycle	76.3	57.3
Iron (electrical and non-electric)	30.3	36

Table B.3: Resident Characteristics compared with all of Zanzibar

Subject	Participating Households by Socioeconomic Status				
	Top	Middle	Bottom	Sample Total	Zanzibar Total
By Residents	(n=208)	(n=236)	(n=272)	(n=716)	
Age of Residents, yrs , (%)					
<18	40	41.5	48.5	43.4	54.1 (< 20 yrs)
18-29	26	20.8	22.4	22.6	15.5 (20-29 yrs)
30- 49	25	19.1	23.0	22.6	19.8
50-69	9.1	8.1	9.9	9.1	9.5
≥ 70	1	1.8	2.6	2.0	1.8
Age Dependency Ratio	63	71	95	77	86

Table B.4: Participant Characteristics compared with all of Zanzibar

Subject	Participating Households by Socioeconomic Status				
	Top	Middle	Bottom	Sample Total	Zanzibar Total
By Participants (ages 18 and older)	(n=127)	(n=138)	(n=140)	(n=405)	
Sex					
Female	53	66	65	184	
Male	74	72	75	221	
Male to Female Ratio	1.4	1.1	1.2	1.2	.9 (all population)
Employment Type (%)					
Employed for wages	31.5	5.1	5.7	13.6	
Self-employed	43.3	55.8	40.7	46.7	
Total Employed (%)	75	61	46	60.7	53.9
Unemployed (%)	16	31	38	28	7.7
Retired	1.6	3	4	2.2	
Seeking	1.6	1.5	.7	1.2	
Disabled	0	0	.7	.3	
Student	31.3	8.0	3.6	14.3	13.9
Other	3.2	.7	3 .2	2.2	

Table B.5: Head of Household Characteristics compared with all of Zanzibar

Subject	Participating Households by Socioeconomic Status				
	Top	Middle	Bottom	Sample Total	Zanzibar Total
By Head of Household Highest Education Level	(N=47)	(N=52)	(N=52)		
Primary I or II	12.8	26.5	48.9	30.4	27.5
Secondary I or II	62.9	55.1	19.1	46.7	42.5
University	7.7	2	0	3	2.2
Masters	2.6	0	0	.7	NA
No Formal Education (%)	7.7	16.3	31.9	19.3	23.3

Table B.6: Household Characteristics compared with all of Zanzibar

Subject	Participating Households by Socioeconomic Status				
	Top	Middle	Bottom	Sample Total	Zanzibar Total
By Household	(N=47)	(N=52)	(N=52)	(N=151)	
Size of Household, avg., sd	5.5, 1.0	5.2, 1.1	5.5, 1.1	5.4	5.6
Number of Children, avg., sd	1.7, 1.3	1.9, 1.3	2.5, 1.5		
Households Assets (%):					
Fridge	28	29	19	25	
Freezer	40	25	15	17	
TV	79	79	71	76	
Computer	17	2.0	0.0	6.3	
Blender	32	44	17	33	
Motorcycle	17	17.3	5.8	13.3	7.1
Car	13.5	9.6	11.5	11.5	2.1
Bicycle	66	73.1	61.5	66.9	33.9
Iron (electrical and non-electric)	57	40	21	33	30.8