Electrifying the Bottom of the Pyramid: Improving Access in Slums

by

Cecilia Scott

Submitted to the Department of Mechanical Engineering
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Slums are expanding in Latin America, Asia, and Africa, and as a result, the lack of safe, reliable electricity access in these regions is expanding. Addressing this issue will require a comprehensive strategy that caters to many different design scenarios. Slum electrification is a complex topic that needs to be closely examined in light of past projects in order to design effective models for future projects. In this thesis, slum electrification is characterized using case studies, case study variations of key characteristics are compared, and new models are proposed for scenarios unique to those found in the case studies. The characteristics are divided into two categories: those of slums and those of slum electrification projects. From analysis of key characteristics, one can see the trend of project actors choosing ideal slum environments and traditional project models for slum electrification projects. Alternative technical and organizational models, such as electric co-operatives and distributed generation, are proposed as potential solutions for less ideal, i.e. less permanent and planned, slum environments. Further development of these potential solutions is necessary in the future in order to make significant gains in the sector of slum electrification.

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Finally, I owe great thanks to my friends and family. My friends have helped me manage to stay sane at MIT, and without my family's support in all of my academic, research, and career endeavors, I would not be where I am today. I am so grateful for all of the opportunities my parents have given me to learn and grow.

I am dedicating my thesis to Jonathan Manson. He and I shared a deep passion for slum electrification, and I hope that I can carry on his work, in one way or another, in the future.

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Chapter 1: Introduction

Many people in the developing world lack access to safe, reliable electricity, and many people in the world live in slums (for definition, see below). At the intersection of these two groups of people are those who live in slum areas without access to adequate electricity. Whereas rural inhabitants frequently lack access to any sort of electricity, slum residents often do have some access. However, this access is limited to illegal or non-formalized connections, which are unsafe and even less reliable than formal connections to the electric grid. Slum residents live in the precarious situation of not having insured electricity access and therefore not having access to other adequate public services that require electricity. Additionally, lack of electricity access prevents business owners from expanding their enterprises and the general population from improving their quality of life through simple measures like refrigeration and electrical modes of communication. Living in an urban setting without being able to easily take advantage of urban services is frustrating and ultimately leads to slum residents finding other less optimal ways to obtain power from the traditional grid.[1]

Some international and national organizations and electric utilities are beginning to deal with this problem through slum electrification projects. These projects are few and far between, at least in terms of extensive documentation. Slum electrification projects are complex because of the inherent complexity of the slums themselves and the numerous actors involved in the electrification projects. In order to expand the number and breadth of slum electrification projects, key technical and organizational characteristics must be determined and experimented with in a wide range of slums worldwide. This paper will characterize slum electrification via case studies, compare and contrast case studies in terms of variations of key characteristics, and propose innovative approaches to slum electrification using other variations of selected characteristics. Through the initial literature review, the author discovered that slum electrification was heavily influenced by organizational structure and implementation, to an extent that these aspects outweighed technological constraints. Both aspects will be included here, with a particular focus on organizational models, but also with consideration of technically advanced models for future projects.

Chapter 1 looks at the different types of neighborhoods which lack access to electricity in urban areas in order to define the term "slum," further discusses challenges associated with lack of electricity access in these neighborhoods, and outlines the proceeding chapters.

1.1 Terminology: Types of Neighborhoods

First, here is a brief explanation of different terms used to describe the regions lacking electricity that will be referred to in this text:

1.1.1 Land Tenure-Based Definitions

These definitions center around who owns the land on which the inhabitants live.

Informal neighborhoods-"Informal" portrays a lot of different aspects of these neighborhoods. The major meaning of the term is that the neighborhoods are located on public lands, rather than private lands. Such neighborhoods, though on public land, are not part of the planned municipality. They are also informal in the sense of not necessarily being planned themselves, along with the buildings in them. They are not formalized or regularized, meaning that they are not officially connected to the electric grid and other public services. Finally, the informal sector refers to those working outside of official businesses, i.e. selling items on the street or partaking in unregistered businesses.[2]

Illegal neighborhoods-This term emphasizes the fact that the neighborhood inhabitants are residing on private lands without paying rent to the owner of these lands and therefore have an illegal status.[2]

Squatter neighborhoods-These neighborhoods are ones in which residents are in the precarious position of not owning the land or housing they are using and also of not paying someone else for its use. This definition is similar to that of "illegal neighborhoods" but places a greater emphasis on the tenancy aspect.[2]

1.1.2 Other Definitions

Spontaneous neighborhoods-"Spontaneous" underlines the unplanned nature of the neighborhoods, in the overall development and individual building schemes. This unplanned nature can be due to a variety of factors, including but not limited to the following: seasonal labor migration, natural disasters, humanitarian conflicts, and economic fluxes.[2]

Ghettos-Ghettos are ethnic enclaves. This term can also refer to an impoverished neighborhood. In either case, ghettos do not necessarily refer to unplanned neighborhoods or those outside of the municipality's boundaries.[3]

Periurban neighborhoods-"Periurban" is used to describe neighborhoods that are located on the periphery of cities.[4] Such neighborhoods frequently are outside of official city boundaries and thus do not have access to public services. Most informal neighborhoods are periurban, as well.

Slums-Slums are the equivalent of informal neighborhoods. However, this term tends to emphasize the poverty aspect of the inhabitants in these neighborhoods. For simplicity, "slums" will be the operative term used here, but not in a pejorative sense. The term "slum" will simply refer to a neighborhood that above all lacks access to public services and may or may not be outside of official city boundaries.

1.2 Background

The remainder of this chapter will provide a brief overview of the issues addressed in this thesis, as well as a summary of the following chapters.

1.2.1 Challenges

Energy Poverty

1.5 billion people worldwide lack access to electricity, and 2.5 billion people lack access to modern fuels. The vast majority of this population is located in developing regions in Africa, Asia, and South America. This lack of access to modern energy services prohibits the underserved population from advancing in economic development, education, and provision of vital services such as clean water, sanitation, and healthcare. Current electrification initiatives will not meet the growing population's needs, and so the number of people without electricity is expected to increase. Numerous studies have found electricity access to directly correlate with poverty alleviation.[5] Bridging the gap of 1.5 billion people or, at the very least, slowing its acceleration is therefore key in combating global poverty.

Environmental Challenges

The energy services that are available to people in developing regions are often harmful to the environment. They can negatively affect environmental conditions on local, regional, and global levels.

Local

The most immediate problem associated with energy services in developing countries is local air pollution. Emissions from wood and other biomass, in addition to other cooking fuels such as kerosene, pollute the air and ultimately people's lungs, causing widespread incidence of respiratory disease.[6]

Regional

Biomass, mainly in the form of wood, is still the major source of fuel for cooking in developing regions. Chopping down wood for cooking fuel can lead to severe deforestation in parts of countries or entire countries.[6]

Regional pollution can also result from the construction and operation of power plants. The environmental quality of electricity sources varies by nation and region, as many developing countries continue to exploit hydropower, a significant renewable energy source. Regardless of the fuel source being used to produce electricity, there are many avoidable technical inefficiencies and therefore losses in electric grids, along with non-technical losses such as electricity theft at the points of distribution. These losses unnecessarily increase the demand on the grid, prompting the electric utilities to build more power plants and increase air pollution in various regions.[6]

Global

Overall, inefficiencies in energy service provision in developing countries translate into unnecessary resource consumption and additional greenhouse gas emissions. Greenhouse gas emissions are generally accepted by the scientific community as contributing to climate change and consequently should be minimized. The effects of climate change are particularly harsh because they extend to all communities and affect all levels of environmental security. Climate change leads to extremes in weather conditions and therefore affects developing regions most, as they are often already subjected to extreme weather conditions on a regular basis. The occurrence of mudslides, flash floods, hurricanes, and other natural disasters is increasing in developing regions, at least in part due to climate change effects.[6]

Slum Growth

About one billion people currently live in slums, including seventy-one percent of the African urban population. This figure is supposed to double to two billion people worldwide by 2030, as more than half of the world population now lives in towns and cities and this proportion is increasing.[7] As urban migration increases, slums are being created and expanding rapidly. There are striking examples of slum expansion in Brazil; this phenomenon in Sao Paolo is depicted above in Figure 1.[8] The expansion of slums results in an increase in the urban poor. These populations' needs, including electricity, must be addressed in sustainable ways in order to avoid exacerbating slum-related problems in the near future.

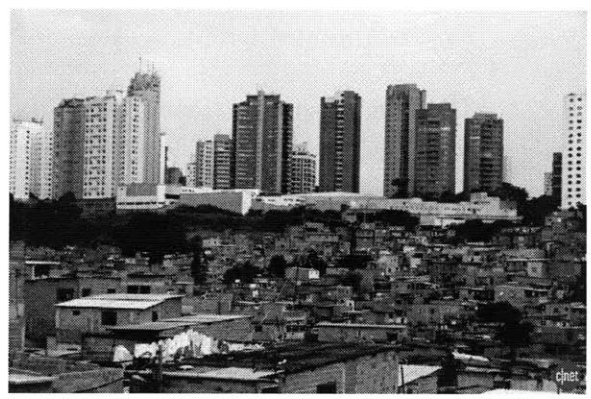

Figure 1: Paraisopolis slum in Sao Paolo, Brazil[8]

1.2.2 Thesis Organization

The above challenges combine to form the topic of this paper: sustainable provision of electricity to slum inhabitants. Slum electrification faces a unique set of issues due to the slum environment and common interaction with the established electric grid. In the following chapters, these issues will be discussed in light of selected slum electrification case studies, and then possible solutions to the overall challenge of slum electrification will be presented.

Chapter 2 will provide a description of the issues surrounding slum electrification, thus establishing the reasoning behind slum electrification projects. It will then summarize the case studies reviewed by the author in light of key characteristics of slums and slum electrification projects. The most prominent characteristics of each project will be compared and contrasted, while referencing condensed matrices of the relevant attributes.

The discussion of past slum electrification projects will lend itself to the proposal of certain project structures for certain circumstances in Chapter 3. Chapter 3 will look at potential policy and financial structures for slum electrification projects, taking into account technical constraints and political objectives. Chapter 4 will serve as the concluding chapter.

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Chapter 2: Analysis of Slum Electrification Case Studies

2.1 Problems Associated with Slum Electrification

There are a variety of problems that contribute to and are caused by the overall challenge of slum electrification. The major issues are divided accordingly and described below.

2.1.1 Organizational Challenges

General Context

The overall conditions in which slum electrification needs to occur, i.e. the neighborhoods, make the process difficult for several reasons. The slums are often built outside of the legal municipality, resulting in slum populations being unable to obtain the same rights and services as other urban populations. Slum residents usually do not own their land or their property, hence complicating logistics in the provision of public services. In addition, since slums spring up through spontaneous mechanisms, the buildings do not necessarily meet the minimum standards, and houses are sometimes built on rights of way and bodies of water or in dangerous geographic areas such as ravines, rendering the residents' status even more precarious. Finally, slum residents are employed in low paying jobs in the formal and informal sectors or do not have jobs at all and therefore have limited means to purchase energy services.[1]

Government

With limited budgets for welfare programs and the burgeoning problem of illegal slum inhabitants in urban centers, governments are often not inclined to provide a favorable environment for slum electrification. These governments do not recognize slum neighborhoods as part of the legal municipality and hence do not require public service providers to serve these areas. Slum improvement and integration programs are present in a number of governments' overall agendas; such programs have resulted in the slum electrification projects that are presented here. Nevertheless, these programs are the exception, with the vast majority of slum neighborhoods being neglected or ignored.[6]

Electric Utilities

In the most favorable political environment, that is, one in which utilities are required to provide 100% coverage in the districts in which they are present, thus forcing them to go into slum neighborhoods, there are still barriers to be dealt with. Utility companies frequently suffer huge losses during the fiscal year. Part of the reason that they choose to not enter slum neighborhoods is that inhabitants in those regions would consume a relatively small amount of electricity, therefore making it difficult for the utility to even break even for those projects, much less make a profit. As they are already in debt, they are not naturally incentivized to take on extra, unprofitable projects. In addition, they may not have the capacity or expertise to deal with the unique structures and situations present in slums.[6]

2.1.2 Challenges Associated with Makeshift Electricity Networks

As a result of these challenges, some slum inhabitants go completely without electricity, while others take matters into their own hands. These residents use their own wires to hook up to the electricity grid at points of distribution (theft) or at a paying neighbor's house (non-regularized connection). The electrical connections are categorized as non-conforming because of their makeshift and substandard nature.[1]

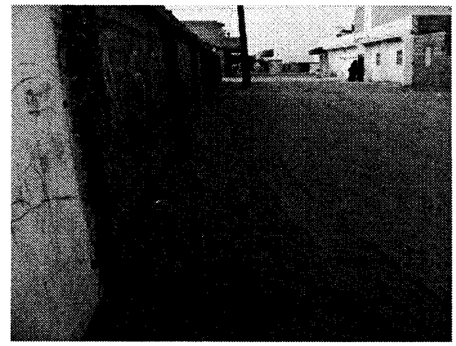

Figure 2: Non-conforming wires above ground in Dakar, Senegal[6]

Safety

A major concern with non-conforming connections is safety. Wires are not buried properly and are sometimes bared, as seen in Figure 2, leading to electrical fires and burns. Children are particularly susceptible to this threat when playing in the streets. Electrical fires also occur at the points of connection to the grid and in homes.[6]

Expense

Those slum customers who are paying their regularized neighbors for electricity access are often charged excessively for these services. Slum residents who are stealing power are frequently consuming much more electricity than they could pay for in a regularized setting. These very different scenarios play a significant role in shaping the slum electrification projects. Highly inefficient electric equipment also consumes more power than necessary, further exacerbating slum residents' financial position.[1]

Quality of Service

In developing countries, quality of service is often poor for normal customers. Electric utilities do not always run efficiently, making outages more frequent. Sometimes, electric utilities will turn off the power in certain regions or cities for weeks, in order to sell it to a higher bidder in a different region or nation.[6]

In slums, these issues are exacerbated by the fact that most electricity users have non-conforming connections. Non-conforming connections are extremely unreliable. The flow of electricity to non-regularized homes is intermittent, due to bad wiring.[6] Activities that depend on a steady flow of power, such as certain medical procedures, are therefore not an option.

Access to Other Public Services

Power-dependent activities include those related to public services. Sanitation and water purification systems require electric pumps and other mechanisms to adequately function. Even basic healthcare facilities have a few pieces of equipment that need power, specifically of constant flow, for important tests and life or death situations. Educational facilities benefit from lighting, which enables them to maintain standard school hours during darker parts of the year. In addition, children have the option of studying in the evening. The absence of a regularized, reliable source of power in slum neighborhoods means that residents do not have access to other key public services. It also makes provision of those services through slum improvement projects extremely difficult.[6]

Social Fragmentation

Slum neighborhoods are not only entities in themselves, but are also frequently sections in much bigger districts that include both slum and urban neighborhoods. Lack of access to public services isolates slum residents from other urban ones. In addition, if the infrastructure is such that slum residents steal electricity or buy it from adjacent regularized households or neighborhoods, newcomers to the neighborhood face difficulties in integrating into the community. They do not have a history in the neighborhood and may therefore be denied public services for a certain period, by virtue of the fact that they lack the necessary connections, both literal and metaphorical, to gain access.[6]

On the other hand, many of the residents are choosing to live in these neighborhoods in part because they are outside of the law, i.e. the residents do not have to pay taxes, pay for electricity and other services, and so on. They are sometimes unwilling to be regularized by utility companies because this leads to becoming urban citizens with other responsibilities. Thus, the fragmentation of slums from the rest of the city is partially a conscious choice that has both positive and negative aspects.[1] One of the challenges for organizations implementing slum electrification projects is to convince slum residents that the positives outweigh the negatives in regularization.

Electric Utility: Technical Losses

The electric utility companies experience both technical and non-technical losses as a result of makeshift slum electrification. Technical losses are those associated with the production and delivery of electricity. Because electricity is being delivered through substandard connections to slum residents, a significant percentage of the electricity leaving power plants is lost in transmission and distribution. This loss pushes the power plants to capacity, as they struggle to provide an unnecessary amount of electricity.[6] Reductions in such losses could prevent utilities from building new power plants to meet increasing demand.

Electric Utility: Non-Technical Losses

Non-technical electricity losses are those resulting from theft. Slum residents sometimes resort to stealing power from the grid. Ironically, this further enforces the electric utility's unwillingness to provide access to slum neighborhoods, as they assume that the power will be stolen regardless.[1]

Environment

While electric utilities in developing countries are often using hydropower, arguably the most established clean energy source, avoidable inefficiencies in transmission and distribution lead to excessive energy consumption. Excessive consumption results in a higher level of greenhouse gas emissions.[1] Additionally, many energy inefficiencies stem from low-quality appliances present in slum neighborhoods, such as incandescent light bulbs and old refrigerators. A vast majority of the refrigerator market in developing regions is filled by secondhand products sent in from the United States (US) and Europe. For example, in Ghana, 80% of the refrigerator market is composed of secondhand refrigerators from Europe. The secondhand refrigerators are particularly bad for the environment, as they emit both GHG's and chlorofluorocarbons, a chemical that damages the ozone layer and has been banned in the developed world.[9] Cooking fuels, which could be potentially replaced by electric stoves, also emit GHG's in addition to polluting the air and hence damaging people's lungs. All of the inefficiencies associated with makeshift slum electrification lead to an increased power demand, encouraging electric utility companies to build more power plants, which have great impact on the environment.

2.2 Slum Electrification Case Study Review: Introduction

Slum electrification is still a relatively new phenomenon. The fundamental challenges due to the unique circumstances in which slum communities and slum electric networks spring up render formal electrification projects in these areas more difficult in some ways than those in traditional urban and rural areas. Consequently, there are few well-documented slum electrification case studies available. The case studies of completed projects examined in this literature review were taken from the following documents: "Innovative Approaches to Slum Electrification",[1] and "Transforming Electricity Consumers into Customers: Case Study of a Slum Electrification Project and Loss Reduction Project in Sao Paolo, Brazil",[10] both drafted by the Bureau of Economic Growth in the Agriculture and Trade Division of the U.S. Agency for International Development (USAID). (USAID used the research summarized in the latter document to structure its Slum Electrification and Loss Reduction (SELR) project in Sao Paolo.) In addition, information from two uncompleted projects was accessed through the document entitled "Powering and Empowering Development: Increasing Access to Electricity in Angola" prepared by the Academy for Educational Development (AED) in conjunction with USAID and through a slum electrification internship undertaken by the author at the European Copper Institute (ECI) in January 2010.[11,6]

"Innovative Approaches" looks at slum electrification projects in the following cities and countries: Manila, the Philippines; Cape Town, South Africa; Rio de Janeiro, Brazil; Salvador, Brazil; and Ahmedabad, India.[1] As indicated in its title, "Transforming Electricity" focuses on USAID's SELR project in Sao Paolo, Brazil.[10] Finally, the uncompleted projects included here are in Luanda, Angola and Dakar, Senegal.

In reviewing the case studies mentioned above, along with participating in the ECI internship, the author began to identify trends in slum electrification, as well as singular attributes of certain projects. These observations led to the creation of a matrix of relevant characteristics, both of the slums and of the slum electrification projects. The author then populated the matrix with the data from each case study. This populated matrix is attached in Appendix A. Characterizing the slums themselves in order to evaluate the potential for electrification projects was a major focus of the internship, and consequently this aspect of the matrix was greatly expanded upon during that time. This matrix, populated with data from the selected neighborhood in Dakar, Senegal during the internship, is attached in Appendix B.

Matrix items of interest, namely, the important characteristics of projects that are similar or different amongst the projects, are highlighted in the condensed matrices provided below. These matrices serve as references for more detailed descriptions of similarities and differences in the following sections. Matrix characteristics will be explained, first for the slum characteristics matrix, and then for the project matrix. The populated matrices will follow. Similarities and differences amongst the case studies will be discussed. Finally, a set of "best practices" based on the case study observations will be presented.

2.3 Case Study Analysis: The Slum Characteristics Matrix

Selected slum characteristics are presented here, and then case study variations are summarized in the slum characteristics matrix in Table 1.

Project Region

This category denotes the continent in which the project is located.

Project Location

This category specifies the city in which the project takes place. This category will be used to identify both slums and projects in the discussion following the matrices.

Slum Name

This category provides the specific slum's name, if specified.

Slum Status

Slum status is crucial in determining the feasibility of slum electrification projects. Both "temporary/precarious" and "permanent" mean many things in reference to slum status, which will be described below.

Temporary/Precarious

Slums are temporary or in precarious circumstances because of many factors, such as geography, politics, recent events, and employment patterns.

*Geographical Location

Part of the reason that slums are not part of municipalities is that they are often located in dangerous or illegal zones. This may be because the slums are in ravines, on mountains, or on bodies of water. They are frequently in regions that are flooded yearly or subject to other dangerous weather conditions. Slums or buildings within the slums are sometimes constructed on rights of way. In this case, the electrification projects cannot extend to residents, because they do not reside on legal tracts of land.[1]

*History

The longer a slum has existed in an urban area, the more likely it is to continue existing without government intervention. In addition, slums become more structured and developed over time. The possibility of slum residents being registered citizens who vote and participate in the community is greater in the cases of older slums. If a slum is relatively new, there is less of a community structure to work with when implementing and monitoring electrification projects.[1]

*Political Status

If the slum is fairly new, the government has less of an incentive to recognize it as a legitimate part of the urban region. Slum residents are less likely to be registered citizens who vote and participate in the greater community. There are fewer community leaders with less prominence, and overall, usually fewer people living in the new neighborhood. These slums are in greater danger of being physically eliminated by the government.[6]

*Natural/Human Disaster

Human disasters such as political and ethnic conflict and natural disasters such as hurricanes and earthquakes lead to the displacement of people to other nations, where they often end up on the outskirts of cities in slums. The status of these slums is uncertain, as the political and humanitarian intent is usually for the displaced populations to return to their home countries and regions when possible.[2]

*Seasonal Labor

Populations living in slums can also fluctuate based on seasonal employment in rural and urban regions. Even if the slums exist throughout the year, having residents frequently changing location makes organizing electricity payments more challenging.[2]

Permanent

"Permanent" slums have the opposite variations of the traits mentioned above. Permanent slums are generally located in geographically safe areas, and permanent buildings are not constructed on rights of way. These neighborhoods are politically well-established and have sufficient ties to the greater urban area, as well as a relatively long history of existence, such that eliminating them by force is not an option. These slums have usually not been created because of population displacement due to natural or human disasters. Inhabitants of these slums have migrated there with the intention of settling there and obtaining employment in the region permanently.

Access to Electricity

This category refers to the slum residents' methods of procuring electricity before the official electrification project. Some residents are simply unable to gain access at all, while others obtain access through theft or illegal service providers (ISP's).[1]

No Access

Some slums or parts of slums are new enough that they do not yet have access to the electric grid present in the urban area. Also, slums can be in geographically dangerous locations that make it difficult for them to gain access to electricity.[1]

Electricity Theft

Electricity theft is prevalent in many slum areas throughout the world. People steal power directly from the grid wires, as depicted in Figure 3,[12] or from mother meters set up in nearby neighborhoods or even in their own neighborhoods. A mother meter is one big meter from which connections to individual houses

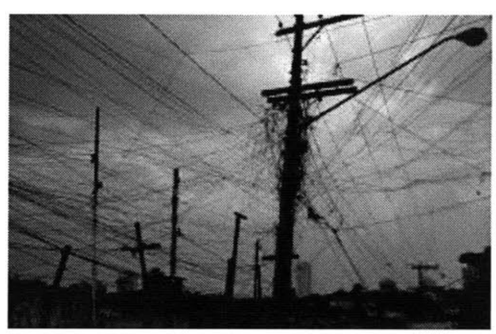

Figure 3: Example of electricity theft in a Brazilian slum[12]

flow and therefore is an easy target for theft. Another issue that arises with electricity theft is that those residents buy many more appliances than they could normally afford to have in terms of electric consumption. When electrification projects are implemented in appliance-heavy areas, people tend to fail to pay their electricity bills, are then cut off from the grid, and begin to steal power again.[1]

Informal Service Providers (ISP's)

ISP's are another significant mechanism through which slum residents received electricity, according to the case studies. There can be several variations that this term applies to. While both major types of ISP's (described below) are technically engaging in illegal activity by selling power without electric utility approval, one type involves theft and the other involves paying the electric utility for the power that is sold on.[1]

***Semi-legal version**

The "legal" ISP is someone who has legal access to the electric grid and connects people who do not have access to the grid and then charges them a premium for their consumption. The ISP could be a savvy businessman or simply a neighbor who feels obligated to share access with his neighbors while simultaneously making money off of the arrangement or at least breaking even. The fees charged for electricity consumption are usually not based on actual consumption but rather are set fees based on the number of appliances in a person's home and other factors. The existence of ISP's places an extra stress on the grid, as the connections from the ISP's to final consumers are inefficient, causing unnecessary technical losses. The flat fees disincentivize the customers from conserving energy, as they can have the appliances on 24 hours a day or 1 hour per day and be charged the same price. ISP's also frequently overcharge their clients, by virtue of the set fees. For example, in the Dakar case, clients are currently paying 60-70% above standard electric utility rates for electricity. On the other hand, when ISP's are the established means of electricity access in a slum community, there is more potential for the success of electrification projects; customers are already paying a premium for electricity, so are more likely to be able to pay for connection costs and electric utility rates. In addition, ISP's allow utilities to make more money without having to invest in expanding the grid to that part of the population. Nevertheless, the inefficiencies caused by electricity delivery via ISP's eventually cause a greater demand for electricity than can be met by existing power plants, forcing utilities to invest an unnecessary amount in power plant infrastructure.[6] Customers of ISP's already pay for electricity, so the electric utility has more of a stake in reaching them than ignoring the need. Additionally, electric utilities would gain the connection fees they are losing in ISP's connecting the customers.

Project Region	Latin America (Brazil)			Asia Pacific	Asia	Africa (Sub Saharan)		
Project Location (Slum Name)	**Sao Paolo (Paraisopolis)**	**Rio de Janeiro**	**Salvador**	**Manila**	**Ahmedabad**	**Cape Town (Khayelitsha)**	**Luanda (Kilambi Kiaxi)**	**Dakar (Pikine)**
Slum Status	permanent	permanent	permanent	permanent	permanent	precarious/ permanent	permanent	precarious/ permanent
Access to Electricity	theft	theft	theft,	theft	theft, ISP's	theft, legal	theft, no access	ISP's, no access
Inhabitants' Land Status	have access to permits	have access to permits	n.a.*	do not own land	have access to permits	do not own land	do not own land	do own land
Appliance Prevalence	high	high	high	high	medium	medium	n.a.	high

Table 1: Slum Characteristics Matrix Based on Case Studies[a,b,c,d]

*n.a.=not available

[a] Reference 1.
[b] Reference 6.
[c] Reference 10.
[d] Reference 11.

***Theft version**

Illegal ISP's steal power from the grid and then sell it at a premium. This scenario is perhaps least ideal in that it combines the problems of theft and ISP's.[1] On the other hand, this means that there are reasons for both the electric utility and the slum residents involved to participate in the slum electrification projects.

Inhabitants' Land Status

Securing land tenure for slum residents is a necessary part of any electrification project. The electric utility companies need to have records of individuals' official addresses in order to bill them (ISP's sidestep this issue by having the bills sent to the regularized homes). Individuals may or may not already have land tenure, depending on other government initiatives to incorporate the slums into the city.[1]

Appliance Prevalence

This section looks at slum residents' appliance ownership before the projects were implemented, though presumably the numbers do not change much because of the projects.

Low

Residents have electric lighting.

Medium

Residents have electric lighting, radio, television, and fans.

High

Residents have electric lighting, radio, television, fans, refrigerators, and electric showers.

The slum characteristics matrix, based on the case study variations of above characteristics, is shown below in Table 1.

2.4 Case Study Analysis: Interpreting the Slum Characteristics Matrix Data

In this section, important slum characteristics matrix data will be discussed in light of differences and similarities amongst projects.

2.4.1 Similarities in Slum Characteristics Amongst Case Studies

Slum Status

The status of the slums is a key feature in understanding what conditions are necessary for successful implementation of a slum electrification project. In all of the projects, the targeted slums were permanent fixtures in the urban landscape that were not going to easily be eliminated by the relevant governments. They were older slums that had at least some formalized housing. They had not sprung up spontaneously due to the presence of temporary migrants or refugees. They were composed of a community of people who had migrated to the area to permanently settle and find work.[1,] This level of stability and, to some extent, planning, is important in the selection process for electrification projects; if the slums are going to be bulldozed within the next few weeks or months, or if they are too crowded and full of unstable, poorly-structured buildings, installing lasting electric networks is going to be very difficult.

Appliance Prevalence

In all completed projects and the current Dakar one, slum residents tended to have fairly large amounts of appliances. In **Brazil**, **Manila**, and **Dakar**, slum residents have especially high numbers of appliances, including refrigerators, while their counterparts in **Ahmedabad** and **Cape Town** lacked refrigerators but still had electric lighting, radios, televisions, and fans.[1,6,10] Where theft was high and appliance use was also high, as mentioned in "**Access to Electricity: Theft**," it was difficult for the project to succeed.

2.4.2 Differences in Slum Characteristics Across Case Studies

Project Region

In **Brazil**, several projects have already been completed, thanks to a favorable regulatory environment, which will be explained in the "**Regulatory Environment**" part, as well as support from USAID and the electric utility companies involved.[10] In **India**, the political environment is also favorable in a less direct way, and thus more slum electrification projects are on the horizon.[1] In Africa, particularly **Sub Saharan Africa**, slum electrification initiatives have begun to take root in recent years and will probably increase in number in the coming decades.[6]

Access to Electricity

Theft

Though electricity theft is present in almost all of the slums in the case studies, the ways in which the issue is handled is different. Several of the other projects addressed the theft issue by installing anti-theft cables and meters. In **Manila** and **Rio de Janeiro**, however, the projects did not succeed because of increased theft weeks after the projects were implemented.[1]

*Manila

The Manila electrification project ultimately did not succeed in part due to the fact that mother meters were installed in the area and were instantly stolen from. Mother meters operate in the following way: An association of households draws service from a single meter on a pole, and individual households pay for electricity based on a sub-metering scheme. Even though these particular mother meters were placed on walls on the perimeter of the slum for high visibility to discourage theft, it still happened.[1]

*Rio de Janeiro

At first, the project in Rio de Janeiro was successful, but because the residents had so many appliances to begin with, they consumed more electricity than they could pay for. Their access was then cut off, compelling them to recommence with stealing power.[1] Appliance ownership is a key component in slum evaluation; electrification projects in high-appliance slums will have to focus on extensive educational and energy efficiency measures to reduce electricity consumption to affordable levels and hence avoid theft.

Informal Service Providers (ISP's)

ISP's are not as common as theft as an alternative for getting electricity in slums. In **Salvador** and **Ahmedabad**, there were theft versions of ISP's.[1] Currently in the slum in **Dakar**, semi-legal ISP's provide power to their neighbors, through multi-connection setups such as the one shown in Figure 4.[6] In a way, this mode of obtaining electricity is more difficult to eliminate, as doing so means taking "jobs" away from these people, who hold some level of power in the community because of their electricity access. A suggested approach to dealing with this issue in Dakar is having the ISP's

Figure 4: Multi-connection ISP setup in Dakar, Senegal[6]

serve as electric utility representatives in collecting electricity bills after the project has extended the grid to other residents. Nevertheless, the feasibility of this solution is questionable, as the electric utility is wary of incorporating the ISP's into their system.

Inhabitants' Land Status

In some projects, housing and/or land permits were made available to project participants. In **Ahmedabad**, project leaders worked with the Urban Development Agency to grant land rights to slum residents in a facilitated process.[1] Again, more permanent slums, such as the one in **Dakar** selected by ECI,[6] are easier to electrify in the sense of being able to skip the land tenure step, so this be a consideration when identifying slums for potential projects.

2.5 Case Study Analysis: The Project Characteristics Matrix

Important slum electrification project characteristics are presented here, and then case study variations are summarized in the project characteristics matrix in Table 2.

Project Size

This category gives the number of households that received power through the project. The main divisions of this category are pilot and large-scale.

Pilot

"Pilot" means that the project serves as a demonstration project, to be potentially replicated on a larger scale in the future if successful. A very small proportion of the total slum population in the region receives electricity through this type of project. This project is intended to serve as a design model for a more comprehensive program.

Large-scale

Large-scale projects are ones that provide electricity to tens or hundreds of thousands of slum residents in an urban area. These projects do not necessarily provide electricity to every resident in a slum, but they do target large sections of a slum in the form of smaller neighborhoods.

Project Structure

Project structure refers to the way in which the project was organized. Generally, there are two methods of formation: top-down and bottom-up.

Top-Down

Top-Down projects are organized by high-level management: in this case, the government, electric utility companies, and international or national non-governmental organizations (NGO's).[1] They face difficulties in translating their big ideas into action on the ground, in local communities.

Bottom-Up

Bottom-Up projects come from within the community, i.e. local NGO's or slum organizations. Their main challenge is to convince the top management that their plans are beneficial to all parties. They also struggle to raise sufficient funding for projects.

Primary Actor in Project

The primary actor in the project is the one in charge of setting up the electricity infrastructure in the slums.

Regulatory Environment

Legislation passed in favor of or against the slums and slum improvement projects can influence electrification projects. The regulatory environment can be described as unfavorable, neutral, favorable, or very favorable.

Unfavorable

In this scenario, the government is actively seeking to physically eliminate the slums by tearing them down, rather than improving them.

Neutral

Public officials may have issued statements favoring widespread electrification or general improvements in the slums, but no official initiatives or legislation are in place. The slums are not likely to be destroyed by the government in the future, but they are also not likely to be improved through government action.

Favorable

This environment includes a government that is generally supportive of slum improvement projects, though slum electrification may not necessarily be a mandate.

Very Favorable

In this case, the government has passed specific legislation directly or indirectly mandating electricity access for slum residents.

Community Involvement

Community involvement refers to the project's primary actors' interaction with the slum community. This involvement can be none, low, medium, high, or very high.

None

Project actors do not communicate with anyone in the actual slum community about the projects they are trying to implement. Without the permission of community leaders and community member cooperation and participation, the projects have little chance of succeeding.

Low

Project actors do obtain the permission and support of community leaders, which leads to general community support of the project. However, community members, particularly local organizations and leadership, are not actively engaged in project implementation.

Medium

There is interaction with community leaders. Local organizations are contracted out to provide materials needed for the electric grid. Nevertheless, slum residents are not properly educated about the project and electricity usage and consumption management.

High

Again, there is a significant amount of interaction with community leaders, as well as contracting of local organizations for materials for and installation of the electric grid. In addition, members of the community are selected to represent project actors in educating people about the project, electricity use and safety, and energy efficiency.

Very High

All of the factors present in the "high" scenario are present in the "very high" one as well, with one addition: the primary project actor is more locally based and therefore has a better understanding of the targeted community and its inhabitants' needs.

Energy Efficiency Upgrades

Many components in the makeshift electric networks and the appliances used in slums are inefficient and unsafe. "Energy Efficiency Upgrades" denotes the replacement of these components or entire appliances with newer, safer ones. All slum electrification projects will inevitably involve what normal electrification projects involve, that is, the establishment of an official distribution system up to the end-use location. However, some projects go further in improving the following two components in households: household wiring and appliances.

Household Wiring

The most obvious and pressing need for energy efficiency upgrades is in the internal wiring, metering, and other components of the makeshift electric network already in place. Such upgrades reduce the risk of injury and avoid technical grid losses. Often, electricity customers do not have the capacity to safely install the household wiring on their own, so project staff will fill this role.[10]

Appliances

Figure 5: Second-hand refrigerators shipped from Europe to Senegal[6]

Many of the appliances, particularly refrigerators, are second-hand and have been shipped from the United States and Europe. Examples of such refrigerators, shipped from Europe to Senegal, are shown in Figure 5.[6] The refrigerators consume an excessive amount of energy and are especially harmful to the environment, as they emit chlorofluorohydrocarbons that damage the ozone layer. Replacing them eliminates these harmful emissions and helps residents reduce their electricity consumption.

Subsidies

The majority of the cost of electrifying slums is in connecting them to the existing grid. Connection costs are high and are difficult for both the electric utilities and the users to pay upfront. Between the utilities and the customers, the burden tends to fall on the customers to pay for the connection costs. They are consequently often subsidized in part or in entirety through government initiatives, international or national NGO grants, and other project actor contributions. Connection costs are usually waived because of government subsidies, whereas connection costs may be lowered because of a combination of government subsides and NGO assistance.[1]

Method of Payment

The slum residents' method of payment may influence the success of the project. The two major options are paying directly after consumption and paying beforehand.

Direct

In projects where direct payment is the method of choice, customers receive monthly bills based on their actual consumption. This approach can be difficult, as customers may not realize how much electricity they are consuming and therefore how large their monthly bills are going to be and are then unable to pay them.

Prepayment

In the prepayment scenario, customers purchase a certain amount of power through local prepaid card retailers. This method of payment for cell phone usage is prevalent in developing countries.[1] However, in case of electricity, there is the disadvantage of intermittent access. As cell phone users are frequently "out of minutes," electric utility clients might not have power for several days during the week, rendering the overall benefits of the electricity less meaningful and encouraging users to steal power in the interim. The prepayment method is also challenging to implement, as the people selling the prepaid cards can become similar to the ISP's in overcharging and forcing bribes out of consumers, thus creating or re-creating the problems associated with ISP's.

Loans

Loans can be a part of either of the two methods of payment mentioned above; slum residents may initially be unable to pay for the electricity and therefore need to take out loans to pay their bills. It is another opportunity for novel microfinance schemes.

The project characteristics matrix, based on the case study variations of above characteristics, is shown below in Table 2.

Project Region	Latin America (Brazil)			Asia Pacific	Asia	Africa (Sub Saharan)		
Project Location	**Sao Paolo (completed)**	**Rio de Janeiro (completed)**	**Salvador (completed)**	**Manila (completed)**	**Ahmedabad (completed)**	**Cape Town (completed)**	**Luanda (in planning)**	**Dakar (in planning)**
Project Size (households)	4,365 (pilot)	250,000	250,000	300,000	820 (pilot)	60,000	1,500 (pilot)	1,250 (pilot)
Project Structure	top-down	top-down	top-down	top-down	top-down	top-down	top-down	top-down
Primary Actor in Project	large, regional utility	large, regional utility	large, regional utility	large, regional utility	large, regional utility	local distribution company	large, regional utility	large, regional utility
Regulatory Environment	very favorable	very favorable	very favorable	n.a.	favorable	neutral	favorable	neutral
Community Involvement	high	high	high	low	high	very high	high	n.a.
Energy Efficiency Upgrades	household wiring, appliances	household wiring	household wiring	household wiring	household wiring	household wiring	household wiring, appliances	household wiring, appliances
Subsidies	connection costs waived	connection costs waived	connection costs waived	connection costs lowered	connection costs lowered	connection costs waived	n.a.	n.a.
Method of Payment	direct	direct, loan	n.a.	direct	direct, loan	prepayment	prepayment, loan	n.a.

Table 2: Slum Electrification Project Characteristics Matrix Based on Case Studies

2.6 Case Study Analysis: Interpreting the Project Characteristics Matrix Data

2.6.1 Similarities in Project Characteristics Amongst Case Studies

Project Structure

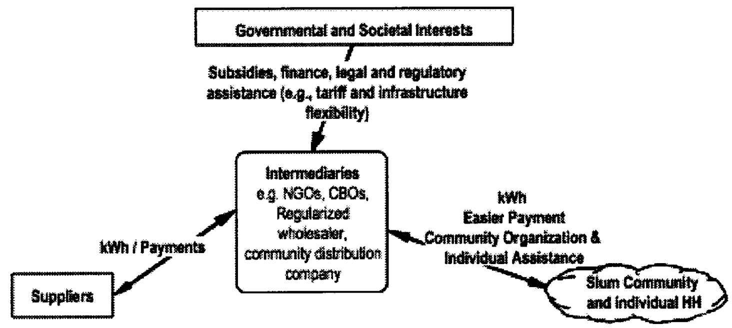

Figure 6: Schematic of Hybrid Organizational Structure Found in Case Studies[1]

All of the projects have a top-down organizational framework, meaning national utilities, national and local governments, and national and international NGO's partner to implement the projects. However, in a way, the overall project structure is a hybrid between top-down and bottom-up, because of the community involvement present in the projects, which is discussed later in this section. The hybrid schematic, taken from "Innovative Approaches," is presented in Figure 6.[1] The pure bottom-up approach to slum electrification is particularly complicated, because of the loose structure of local organizations and the quickly evolving nature of the slums themselves. These factors render the slum electrification projects challenging for any organizations of any scale, as there are expenses and on-the-ground work that must be covered by some project actor or actors.[6] Nevertheless, smaller, local organizations have expertise in interacting with the slum neighborhoods that can be useful and should be incorporated in the future. In addition, power generation within the slum community itself could work, in reducing theft and creating employment opportunities. The bottom-up approach should be further explored and developed, and the hybrid model seen in these case studies should continue to be supported in the future.

Primary Actor in Project (except in Cape Town)

The primary actor in every project except the Cape Town one is the electric utility company. This trend is due to the fact that all of the projects have been ones in which the grid is extended to the slums. The natural choice is therefore to work with the major electric utility, which has the capacity and resources to take on the project. In any case, the major electric utility must at least approve of the grid extension project in order for it to be viable.

Energy Efficiency Upgrades-Distribution System

All projects involved replacing internal wiring and meters with new, safer, more efficient components. This action is a necessary component of any slum electrification project.

2.6.2 Differences in Project Characteristics Across Case Studies

Project Size

Pilot

The project in **Sao Paolo** and the ones proposed for **Luanda** and **Dakar** are pilot projects by development aid organizations,[6,10,11] namely USAID, AED, and ECI, thus they were much smaller. The **Ahmedabad** project was also a pilot project, initiated by the local government because of a larger government initiative.[1] In general, extensive slum electrification programs begin with small pilot projects and expand as organizations learn from their experiences.

Large-scale

Project size differs in part because of intent and in part because of government support. The specific regulatory environments will be described in the "**Regulatory Environment**" section but in general, the Brazilian government is very supportive of slum electrification initiatives. Thus, the projects in **Brazil** were more long-term and extensive. **Manila**'s program was also heavily supported by the government.[1]

Primary Actor in Project-Cape Town

The one exception to the electric utility-as-primary-actor trend is in **Cape Town**, where PN Energy, a local electricity distribution company, was charged with delivering electricity to slum customers. The intention behind this structure was to select an actor that already knew the region very well, particularly the specific neighborhood in which the project was to be implemented.[1] The approach was successful and should be considered in future projects as a viable alternative to the traditional electric utility management structure.

Regulatory Environment

No projects took place in a regulatory environment in which the governments were trying to displace slum populations by destroying their neighborhoods. In general, the regulatory environment for projects outside of Africa is favorable to some extent, whereas in Africa, it is neutral.

Neutral

In **Africa**, governments are supportive of slum electrification programs in a muted way. There is currently no favorable legislation or national initiatives in the cities covered in the case studies. Additionally, Africa utilities are generally struggling more than their Brazilian counterparts to make a profit. Adding on projects with low volume and therefore little or no profit would be difficult, and hence, a mandate would be difficult for the government to enforce.[6]

Favorable

A more general supportive government program exists in **India**. The Indian government has set the goal of eliminating all slums by 2016. This national goal served as the motivation for Ahmedabad's electrification program.[1]

Very Favorable

In **Brazil**, a government mandate has led to a nationwide slum electrification program. This mandate was the following: electric utility companies must provide 100% coverage in the areas they serve, meaning that the slums in urban areas must also receive electricity.[10] The mandate is crucial in encouraging electric utilities to extend the grid to slum neighborhoods, which may not always be profitable.

Community Involvement

There were different levels of community involvement in the projects reviewed here, but all projects engaged the community to some extent.

Low

Another flaw in the structure of the **Manila** project was that the organizers did not make connections with local actors and therefore did not receive adequate local support. The national NGO overseeing the project did not wait around for local NGO's to get up to speed on the project and simply undertook the project alone.[1] At the time, this advancement without strong local partners seemed necessary, but perhaps waiting and consequently garnering more local support would have been advantageous for the project.

High

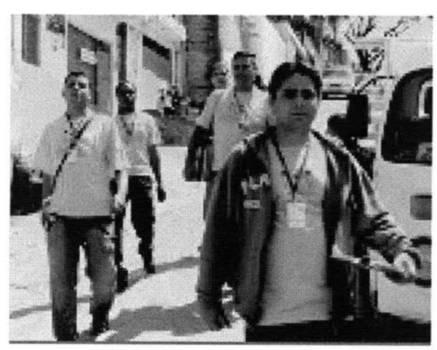

Figure 7: Community agents in Sao Paolo, Brazil[10]

Projects in **Brazil** had high community involvement. Specifically, residents of the slum communities in Brazil were selected to be community agents who promoted the project, seen in Figure 7, who promoted the project and educated users on how to manage electricity consumption and payment.[10] In **Dakar**, ECI plans to follow suit by partnering with local electric equipment companies for the internal wiring and meter components of the slum electric infrastructure and with a local

NGO to educate users about electricity consumption and budget management.[6]

Very High

The project in **Cape Town** had very high community involvement by virtue of the fact that the primary actor was a local distribution company, rather than an electric utility company.[1]

Energy Efficiency Upgrades-Appliances

Old, inefficient appliances should be replaced during the projects, in addition to materials comprising the electricity distribution network. However, only the **Sao Paolo** project has addressed the appliance issue by replacing inefficient refrigerators and distributing compact fluorescent light bulbs.[10] The **Dakar** and **Luanda** projects intend to follow this example.[6,11] Such an initiative requires extra funding, resources, and project partners and is therefore less attractive in terms of being incorporated into slum electrification programs. Nevertheless, it should be considered in future projects, because it can ease customers into the regularization and payment process and is beneficial to the grid and to the environment.

Subsidies

Connection costs were lowered or waived in all of the completed projects. In the **Brazilian** and **South African** cases, connection costs for slum residents were waived through a government subsidy.[1,10] Connection costs were lowered in the **Manila** project through a government subsidy, and connection costs for the **Ahmedabad** project were divided equally amongst the Ahmedabad Electricity Company, USAID, and the customers.[1] Future projects, such as the one in **Luanda**, may consider establishing a revolving loan fund in lieu of subsidies to front connection costs and sustain a comprehensive electrification program.[11] Innovative financial mechanisms should be investigated for future projects.

Method of Payment

All of the projects necessitated slum residents paying for the electricity they consumed. The groups that had to pay in part for connection costs did so through loans. Most projects had users pay for the electricity directly after consumption, whereas the **Cape Town** one used a prepayment method. Slum residents in Cape Town purchased prepaid cards from local retailers and used prepayment meters to obtain electricity.[1] This method was successful in this specific case, but may be more difficult to sustain in a long-term, large-scale program.

Chapter 3: Design Models for Future Slum Electrification

3.1 Slum Electrification Case Studies: Preferable/Most Successful Characteristics

Through the case studies, one can identify variations of characteristics that are favorable and/or positively impacted project success. These variations are not necessarily crucial to any such project's success; they are merely an indication of what has proven effective in the domain of slum electrification in the past, and within what context the successes have occurred. The variations of slum and project characteristics are summarized briefly below.

3.1.1 Optimal Case Study Slum Characteristics

Based on the case studies, the following slum characteristics are desirable when attempting electrification projects:

- Permanence
    - Historical establishment
    - Geographical stability
    - Political recognition
    - Permanent residents
- Availability of land tenure for slum residents
- Electricity access through semi-legal ISP's
- An affordable amount of electric appliances

While not all of the case study projects involved slums with all of the above characteristics, all of the slums were at least partially permanent in terms of status, and most were well-established. In addition, high access to appliances implied a certain level of wealth in the cases lacking significant electricity theft.

3.1.2 Most Successful Case Study Project Characteristics

Within the aforementioned slum context, case study projects succeeded when the following characteristics associated with the overall context and project structure were present:

- Supportive regulatory environments
- Hybrid combination of national electric utilities or local distribution companies, national and international NGO's, and local community partners

Two major categories that have unrealized potential within the case studies' specific contexts are the following: appliance efficiency upgrades and financing mechanisms. Despite the fact that many slums in the case studies had high appliance usage, only one completed project, as well as one project in development, implemented a refrigerator replacement scheme to improve energy efficiency. In addition, innovative financing schemes were not developed in the completed projects, despite the existence of a wide range of options in terms of financial services for lower-income populations worldwide.

3.1.3 The Dakar Project: Partially Straightforward, Partially Innovative

In my internship with European Copper Institute in January 2010, I gained insight into the planning of the slum electrification project to be implemented in Dakar later this year. Having observed slum electrification projects from both the outside and inside, I can more fully appreciate why past ones possess many of the same characteristics.

Figure 8: Housing in Pikine, the Dakar slum that is targeted in ECI's pilot project[6]

First, the organizations implementing the projects often choose slums according to potential for success. In the Dakar case, the selected slum was actually created by the Senegalese government over fifty years ago, to decrease congestion in Dakar's city center. The vast majority of residents of the specific neighborhood within the slum which will be electrified have land tenure, pay for their electricity through semi-legal ISP's, and have huge numbers of appliances: an average household has 11 lamps, plus a refrigerator and other electric equipment. The average income within the neighborhood is equal to that of the greater metropolitan area of Dakar. The relative stability and large size of housing structures can be seen above in Figure 8.[6] This neighborhood is therefore a slum only in the sense of not having formalized electricity access. Projects in such slums demonstrate an "easiest-case" scenario, rather than resulting in a set of best practices that can be applied to very different types of slums.

Additionally, project implementation groups frequently stick to the traditional grid extension model, because it is the safe bet. It has been widely used in urban areas, and therefore integrating the model into the ideal slum scenario is not a huge risk. The Dakar project is trying to develop beyond the traditional model in the sense of creating a refrigerator recycling program which is intended to be adopted in the entire region of West Africa, and in exploring various financing mechanisms.[6] However, slum electrification projects appear to be understaffed and underfunded, at least in the case of European Copper Institute. Organizations are consequently much less willing to take risks and try innovative strategies, as implementing a straightforward project in a well-established, relatively wealthy slum is a big enough challenge.

A semester-long literature review of slum electrification case studies yielded only eight comprehensive case studies, all of which were sponsored by USAID and/or the International Copper Association. This could also factor into the similarity amongst project structures and results.

3.2 Alternative Scenarios and Models for Slum Electrification

The models found in the case study projects cannot be applied to the many unique circumstances in which slum electrification must occur in the future. As this sector expands, new models will need to be developed to fit less ideal contexts. The global slum population is supposed to double in twenty years, thus creating many new, and therefore less permanent, slums. In addition, even in the case of permanent slums, regulatory and industry environments are not always as favorable as those apparent in the case studies. This section does not attempt to describe every context and corresponding electrification solution. Rather, it outlines several major scenarios, unique to those present in the case studies, in which slum electrification could occur, and offers potential design models for these scenarios. The design models are not posed as solutions, but rather as questions in beginning the search for more innovative approaches to slum electrification.

3.2.1 Permanent Communities, Imperfect Contexts: The Sustainable Co-op

Even when slums are well-established in the urban community, the political environment may not be conducive to electrification projects. If the regional utility is running a deficit, and there is no legislation mandating slum electrification, grid extension has to happen through other types of project actors. This scenario is common in Sub Saharan Africa, where utilities struggle to make a profit, and political support for slum improvement is slowly growing.[6] For example, the Dakar scenario has these disadvantages and is trying to deal with them through outside grants and individual payment for connection costs. There is another funding and operation mechanism, which emphasizes the community rather than the individual: the co-operative.

The co-operative (co-op) electrification model is one in which a group of people takes out a loan to build proper electric infrastructure and then provides electricity to the surrounding community. Co-ops are usually non-profit; they pay the utility a fee for use of grid-based electricity, and then channel any other profits into expanding the neighborhood grid as the neighborhood grows. Co-ops may charge higher fees for electricity than the national electric utility does, but the extra cost contributes to sustainable community infrastructure. Rural electrification in the US largely happened through non-profit co-ops.[13]

Electric co-ops would inevitably vary in slums in developing countries from those initiated in the rural US, but the model could still be applied. For example, the scale of slum electric co-ops would be very different from that of American rural co-ops. Whereas American rural electric co-ops basically functioned as municipal utilities in serving several counties, i.e. thousands of people, slum electric co-ops would more likely serve populations in immediate neighborhoods, which would number in the hundreds or perhaps, in extreme cases, in the thousands. In addition, American electric co-ops used funds from the federal Rural Electrification Act to build up infrastructure; in the absence of a favorable regulatory environment, slums would not have the same access to government funds.[13] However, there are an increasing number of financial services available to the urban poor in developing countries. Energy entrepreneurs within the community could form a co-op and acquire the necessary loan through a microfinance institution. As with the American electric co-ops, slum electric co-ops would help to create jobs within the community, increase training and skills of workers, and provide a valuable service to slum residents.

Another difference between traditional electric co-ops and slum ones is that of the quality of the electric grid involved. In slums, being connected to the grid does not as easily ensure a steady electric supply. In order to ensure reliability in the long-term, slum co-ops would have to incorporate local sources of power into the community's portion of the citywide grid. This could be an opportunity for further enterprise and job creation in the neighborhood, as well as introduction of more environmentally friendly sources into the community grid.

Overall, the co-op structure has potential in the permanent slum environment because of the sense of community there. It would be a way to formalize the ISP's role and expand it in a more equitable way. It could also discourage theft; members of the community would be disincentivized to steal electricity from the owners of the co-op, as neighbors. The stability of the community structure is vital to electric co-ops' success, and therefore, other strategies may be more effective in less permanent slums.

3.2.2 Spontaneous and Less Permanent Slums: Distributed Generation

Slums are springing up across the globe. Slums are often formed in the short term, rather than on a longer timescale, because of drastic changes in local circumstances. Such changes include natural disasters, humanitarian conflicts, and fluctuations of industry presence in a region. Less permanent slums can also have that status because of an ever-changing population, thanks to seasonal labor patterns or other motivations for frequent migration. Because these types of slums are new, relatively unplanned, and full of temporary inhabitants, they often do not immediately gain political recognition and are consequently not high up on the slum electrification agenda. Without easy formalized access to the grid, the slums must look for other methods of sustainable electrification. One off-grid method that is currently being implemented in rural regions in developing countries is distributed generation (DG).

As with the co-op, distributed generation focuses on a community-oriented design, to some extent. Energy entrepreneurs generate power through small-scale energy technologies and then establish connections within the neighborhood through which residents receive electricity. A certain amount of space is needed for the successful operation of the various technologies, and in general, a certain level of order and trust within the community has to exist in order to avoid theft and destruction. In addition, capital costs per kilowatt are usually higher than those for a large power plant.[14] However, given the circumstances and the small scale of distributed generation in slums, these costs could be qualitatively outweighed by the advantages of safe, reliable electricity.

Again, there are differences between how rural DG works and how slum DG would work. To clarify, rural DG projects are defined here as those that provide power to an entire village or several houses, as opposed to household mechanisms such as solar kits, which include a solar panel, battery, and some fluorescent lights. In a rural area, DG is frequently a government-led initiative.[15] In contrast, in a less permanent slum, where there is not necessarily a structured local government, the establishment of a DG network probably would begin with individuals or groups of individuals—energy entrepreneurs—deciding to start enterprises which entail generating and delivering electricity to the surrounding community.

Distributed generation, whether in rural or slum regions, can include numerous energy technologies, many of which are considered renewable. Combinations of solar photovoltaic, wind, and diesel-generated power are particularly common in rural areas.[15] An example of a solar-wind hybrid system is shown in Figure 9.[16] Depending on the climate and situation of slums, such hybrid systems could presumably work similarly in slums. Hydropower systems are relatively common in rural areas, and biogas digesters are becoming increasingly popular to use to produce both electricity and cooking fuel; however, these technologies require energy sources not commonly available in urban areas and are therefore less relevant to a slum DG model.[15] Ultimately, the important thing is for the energy entrepreneur to choose the technology that is most cost effective and technologically feasible in the local environment. If the electricity-generating technology works well, good quality of service will result, thus optimizing reliability gains from off-grid power while minimizing costs.

Figure 9: Solar-wind hybrid system in rural India[16]

Once the energy entrepreneur has selected an electricity-generating system and a financing mechanism for the project, he will target early adopters, i.e. his first customers. Rural DG electrification usually happens in more comprehensive terms; an electrification project will result in an entire village or large segment of the village gaining access to electricity.[15] However, in the case of slum DG electrification, order needs to be established within the slum as the slum is increasingly electrified. The energy entrepreneur also does not necessarily have access to large enough loans to take on such massive projects; he needs to build up his capacity gradually. Hence, an energy entrepreneur will not attempt to electrify an entire slum initially, but will instead try to reach major public service buildings and institutions within the slum. For example, buildings such as schools, hospitals, and water purification facilities require electricity to function efficiently. Given that the slum may be fairly new and lacking in electricity access, other public services may not be available beforehand. DG would encourage such service institutions to be constructed and would ideally lead to a collaborative establishment of sustainable public infrastructure within the neighborhood.

The energy entrepreneur would then target businesses within the community. Business owners may historically have had access to microfinance loans and may be looking to expand their enterprises, which makes them prime candidates for being hooked up to the DG grid. In the case of a lack of public institutions in a slum, businesses would be the first customers.

The final targets would be housing structures. By this point, the energy entrepreneur would have gained the experience and perhaps the profits needed to expand the business to reach all slum residents, while continuing successful operation and maintenance of the DG grid. As the customer base expanded, DG technologies could also increase, in number or type, further diversifying the DG grid. Because entrepreneurs would be based in the community in which they were providing electricity, they would more easily be able to keep track of who moved in and out. If the energy entrepreneur was producing excess capacity, he could potentially sell this power to the traditional grid, which would aid the regional utility in increasing its grid capacity and consequent reliability.

Ultimately, DG has potential as a less permanent slum-based method of electrification because of its social and technological advantages. DG is a model that could have a positive impact on slum communities because of its involvement of a variety of local actors. Through both DG and co-ops, people in the community would have a sense of ownership of the electric supply, rather than being subjected to the whims and struggles of the regional electric utility. This would not only be empowering but would also encourage job creation and training within the neighborhood, while discouraging theft from the DG network or regional grid.

In terms of technology, many of the micro-generation options are more environmentally friendly than their regional grid counterparts, making DG projects more attractive when applying for grants and loans. Solar and wind are common renewable energy sources being developed worldwide.[14] The Dakar project is struggling to receive funding because of its traditional grid extension structure, whereas a rural DG counterpart is much more likely to get the competitive grant. Incorporating DG into slum electrification projects could encourage more of them in the near future, because of funding availability. In addition, micro-generation units are much more mobile than traditional stationary sources, giving them potential for refugee situations, where the populations may be moving to another location soon and want to take the electric equipment with them.

3.2.3 Geographically Precarious Slums: Restructuring or Relocation?

The case of slums located in geographically unstable places is especially challenging. These slums may be subject to excessive flooding or other hazards several times a year, which can easily destroy any electric or other infrastructure. The primary goal in these cases should be to first establish stable conditions. Whether this stability is achieved through technical solutions in the immediate region or through relocation to a safer area, it is a prerequisite for allowing access to electricity and other necessary services. Once the neighborhood is geographically stable, there can be further discussion of electrification options such as traditional grid extension, electric co-ops, or DG.

Chapter 4: Conclusion

Slum electrification is a complicated subject that entails an examination of a multitude of design criteria, both in terms of slums and slum electrification projects. Through eight case studies, the author determined the key criteria for slum electrification projects and made observations about how they varied amongst case studies and the corresponding reasons for this variation. Overall, the case study projects were implemented in permanent slums, where the inhabitants frequently had access to land tenure, had access to electricity through theft or ISP's, and owned a relatively high number of appliances. The slum electrification project structures were also similar, with most being a hybrid combination of top-down government, electric utility, and NGO leadership, with high interaction with local manufacturing and training partners and slum community leadership.

The case study conditions represent an easier context in terms of project feasibility. When evaluating project feasibility in the future, different, and perhaps more innovative, project structures should be crafted in dealing with less ideal slum circumstances. The case study slum circumstances are by no means the only context in which slum electrification could potentially occur. In areas where regulatory environments and the motivation of electric utilities are not in favor of slum electrification, grid extension could occur through community co-ops, which could then by supplemented by locally generated electricity as the community grew. In spontaneous or less permanent slums, distributed generation could be an option that offers enough flexibility in terms of generation sources, changing capacity, and migrating populations to meet these slums' needs. There are some factors that would render slum electrification nearly impossible in certain neighborhoods, such as geographical instability and annual exposure to extreme weather conditions, but even in such situations, technical and relocation options could be explored. In any case, the process of choosing appropriate technical, organizational, and financial models based on the slum's physical and organizational structure, as depicted below in Figure 10, is vital to project success and should allow the sector to expand in new directions.

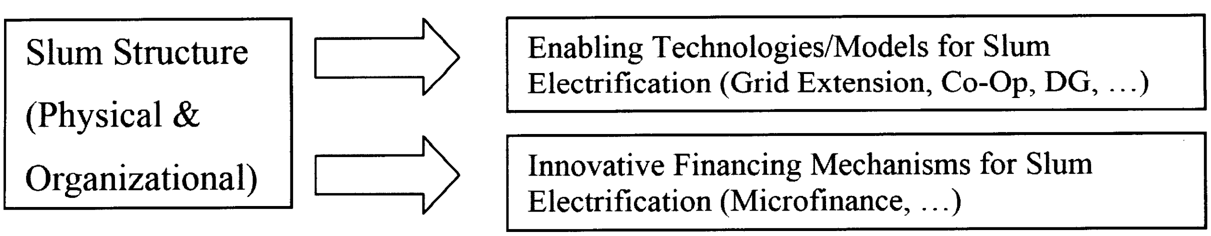

Figure 10: Schematic of Slum Electrification Design Process

Nevertheless, comprehensive slum electrification is a daunting challenge. NGO's, regional utilities, and other project leaders, for which slum electrification projects are often understaffed and underfunded, will naturally choose the easiest slums to electrify, because even these circumstances do not lead to simple, successful projects by default. In addition, energy access in slums remains to be seen as a priority worldwide, with other public services such as clean water and sanitation treated as more vital. Ironically, these services are usually not feasible without a safe, reliable electricity supply. Electricity's connection to many other public services within slums needs to be further emphasized in order for slum electrification to become a global mandate. With the mandate will come funding, and with funding will come more opportunities to experiment with new electrification models in new contexts. Ultimately, the future of slum electrification is inextricably linked to the future of slums; the test of time will show whether or not slums will be legitimized in a widespread fashion by governments, and consequently, whether or not sustainable slum electrification will be possible.

Appendix A: Case Study Slum Electrification Characteristics Unabridged Matrix

The matrix provided below was created during the case study literature review in Fall 2010, before the internship with ECI. Dakar is therefore not included in this matrix, but data from that project can be found in Appendix B. This matrix has more specific information in some cases about the criteria variations. For further information, see References 1 and 10.

	Sao Paolo	Luanda	Manila	Cape Town	Rio de Janeiro	Salvador	Ahmedabad
Before Project							
Slum Info							
Slum Size	2nd largest in Sao Paolo	densely populated		50,000 houses			
Slum Status	relatively well established		mixed in with other resident and indus sites	mixed: precarious and permanent	permanent (old)	permanent (old)	permanent
Slum Location	ravine		rights of way, bodies of water		on hillsides	on hillsides	oldest part of town (near factories)
Slum Access to Electricity	theft	ISP's	theft	some legitimate	theft	ISP's, theft	ISP's, theft
Slum Crime Rate	relatively low b/c surrounded by wealthy			high	high		
Incidence of Theft (Before)	High		high	medium	very high	high	high
Electricity Consumption (Before)	250 kW/month			20%-150 kWh	high	96-139 kWh	

	Sao Paolo	Luanda	Manila	Cape Town	Rio de Janeiro	Salvador	Ahmedabad
Slum Inhabitant Profile							
Inhabitants' Housing	concrete blocks		wood, steel, multiple families/house	20% permanent, 80% informal		small house with several rooms	
Inhabitants' Land Status	access to permits	don't own land on which their houses are built	don't own land, in precarious locations	don't own land	access to permits through project		access to permits through project
Inhabitants' Employment	30% informal, employed in nearby area		informal, jobless, or scavenger	20-50% unemployment rate in informal		informal, unemployed	
Inhabitants' Appliances	refrigerators, electric showers		electric lights, radio, tv, fan, refrigerator	electric lights, radio, tv, fan	electric lights, radio, tv, fan, refrigerator	electric lights, radio, tv, fan, refrigerator,	electric lights, radio, tv, fan
Project Info							
Primary Actor	AES Eletropaulo (utility)	EDEL (utility)	MERALCO (utility)	PN Energy (local distribution co)	LIGHT (utility)	COELBA (utility)	Ahmedabad Electricity Company
Organizational Structure	Top-Down (utility, gov, NGO's)	Top-Down (utility, gov, NGO's)	Top-Down (utility, gov, NGO)	Top-Down (multiple utilities + PNE)	Top-Down (utility, World Bank)	Top-Down (utility, NGO)	Top-Down (utility, NGO's)
Regulatory Environment	very favorable	favorable		neutral	very favorable	very favorable	favorable
Method of Payment	inidividual payment	prepayment, revolving loan fund	participants had to pay connec costs, pay bills	pre-paid cards for prepayment meters	non-recourse debt		direct payment, loan for connec costs
Energy Efficiency Measures	household wiring, refrigerators	household wiring, cfl's[a]	household wiring	household wiring	household wiring	household wiring	household wiring
Project Size	4365 households	1500 households	300,000 households	60,000 households	250,000 households	250,000 households	820 households
Community Involvement	high (community agents)	high	almost no collab w/local NGO's	very high (distrib co)	high (teenage community agents)	high (community agents)	high

	Sao Paolo	Luanda	Manila	Cape Town	Rio de Janeiro	Salvador	Ahmedabad
Low-Income Subsidies	connection costs waived		connection costs lowered	connection costs waived	connection costs waived	connection costs waived	connec costs split b/w USAID, AE
Public Lighting	yes			yes	yes		
Special Measures	initial cap on electric bill-150 kWh per month	town hall meeting,GIS mapping[b]		first 50 kWh free	free cfl's, community initiative to	cfl swap, discount rates for low-	free cfl's, WTP surveys,[c] women's rights
<u>After Project</u>							
Incidence of Theft	low		lower, then high	reduced by 65%	lower, then high	lower	
Electricity Consumption	150 kW/month				lower, then high		

[a]cfl=compact fluorescent light bulb
[b]GIS=Geographic Information System
[c]WTP=willingness to pay

Appendix B: Comprehensive Slum Characteristics Matrix (Produced During ECI Internship)

This matrix was created as part of my internship with ECI in January 2010. I started out with a laundry list of slum characteristics and then adjusted it according to my colleagues' suggestions. I began populating the matrix with data from the slum that was being targeted in Dakar—Pikine. Pikine is divided into two major parts: the older, more established part, and the newer, less planned part. These sections are referred to in Senegal as "Pikine regulier" and "Pikine irregulier," respectively. I attempted to populate the entire matrix with data on the two sections of Pikine, but due to a lack of information, was unable to obtain relevant information on all of the criteria. Overall, this assignment was intended to begin the establishment of a slum database in order to facilitate electrification projects and other improvement projects.

Slum Characteristic	**Possible variations**	**Pikine- "regulier"**	**Pikine- "irregulier"**
Physical			
Size (km^2)	large, medium, small	95 km^2 (entire)	95 km^2
Location (land)	on stable ground, on unstable ground and/or dangerous landforms	in Niayes valley, parts are on stable, fertile ground, others on flood-prone ground	in Niayes valley, most parts are on flood-prone ground
Location (proximity to city center in km)	near (0-5 km), medium (5-10 km), far (10+ km)	far (15 km from Dakar)	far (15+ km from Dakar)
Location (proximity to bodies of water)	near, far, on top of	near river	near river
Density of buildings per hectare of land	high, medium, low	light/medium	light to medium
Population			
Country of origin	slum country, Other	Senegal	Senegal
Citizen status	legal, illegal	legal	some legal and illegal
Immigration (percentage breakdown)	rural-urban immigrant, urban-urban immigrant, foreign immigrant, native, refugee	immigrants from the interior of Senegal that were former residents of Dakar	immigrants from interior of Senegal, some former residents of Dakar

Slum Characteristic	**Possible variations**	**Pikine- "regulier"**	**Pikine- "irregulier"**
Level of migration permanence	permanent, temporary	permanent	permanent/ temporary
Level of preconception of migration	preconceived, unplanned	preconceived	mostly unplanned
Community Size (number of people)	large (>1 million), medium (500,000-1 million people), small (<500,000)	800,000-1 million (entire Pikine)	800,000-1 million (entire Pikine)
Household Size (number of residents)	large (>10 people), medium (5-10 people), small (<5 people)	medium (8-10 people)	
Administrative Quarter Size (division of population within the community	large, medium, small		
Ethnicity (percentage breakdown)	varies	mostly Senegalese	mostly Senegalese
Religion (percentage breakdown)	varies	Muslim	Muslim
Age (% breakdown)	unemployable, employable		
Employment	formal, informal		
Employment location	in slum, outside of slum	outside of Pikine (Dakar)	
Employment timeframe	permanent, temporary, seasonal	permanent	permanent
Income level (per household)	<$1/day, $1-2/day, >$2/day	>$2/day	$1-2/day
Context			
Number of businesses in slum	prevalent, average, few		
Level of establishment in city	old, New	old	relatively new
Reason for creation	migration over time, emergency, war	relocation from Dakar by government for new developments	spontaneous- migrated from other parts of Senegal, forced to move

Slum Characteristic	**Possible variations**	**Pikine- "regulier"**	**Pikine- "irregulier"** from Dakar
Housing			
Construction strategy	spontaneous, planned	planned	spontaneous
Housing type	house, apartment building	mix of houses and apartments	
Number of rooms	large (>5 rooms), medium (2-5 rooms), small (1 room)	large	
Types and number of appliances in home	refrigerators, electric lighting, electric showers, electric stove, gas stove	refrigerators, electric lighting	
Lighting source	electric (incandescent, CFL, LED), kerosene, petroleum)		
Cooking source	gas, wood, charcoal, biomass		
Method of food conservation	cooling: refrigeration, ice; drying		
Number of times woman cooks per week	often (2-3 times per day), regularly (1-2 times per day), infrequently (2-3 times per week		
Legality	legal structure, illegal structure	legal structures	mostly illegal structures
Materials' durability	durable, not durable	durable	less durable materials
Location	on rights of way, on legal ground	on legal ground	illegal ground: in flood-prone areas
Land status	has or does not have land tenure	has land tenure	does not have land tenure
Housing timeframe	temporary, permanent	permanent	
Housing/land ownership (percentage breakdown)	owner, tenant		
Security			

Slum Characteristic	**Possible variations**	**Pikine- "regulier"**	**Pikine- "irregulier"**
Level of crime in immediate neighborhood	low, medium, high		
Level of crime in surrounding neighborhood	low, medium, high		
Finance			
Bank account ownership (percentage breakdown)	yes/no		
Saving/loans mechanism	bank, tontine, microfinance		
Society			
Leadership	official government, religious, patriarchal, matriarchal, hereditary	official government	
Status of women	have lots of power or lack power	have little power	
Access to public services			
Electricity	legal, illegal, theft, none	legal	mix of legal and illegal
Clean water	yes/no	yes	no
Sanitation	yes/no	yes	no
Public roads and infrastructure status	well-developed, under construction, non-existent	well-developed	some infrastructure
Population aged 10-15 in school (% & #)	high (65% and above), medium (35-65%), low (Below 35%)		
Population with access to functioning health center (%)	high (65% and above), medium (35-65%), low (Below 35%)		
Political environment			
Regulation supporting access to services in peri urban regions	yes/no	no	no

Slum Characteristic	**Possible variations**	**Pikine- "regulier"**	**Pikine- "irregulier"**
Government recognition of peri urban community	yes/no	n/a	little or none
Electricity			
Current meter set up	mother meter, individual meters	individual meters	
Method of payment	cash, loan, bank transfer		
Payment timeframe	monthly, longer period, irregular payment, prepayment		
Non-conforming connections (percentage breakdown)	conforming, non-conforming		almost all non-conforming connections
Incidence of electricity-related accidents	high, medium, low		

References

[1]C. Smyser, W. Annecke, S. Maia, M.L. Vitelli, and J. Sullivan, "Innovative Approaches to Slum Electrification," (United States Agency for International Development (USAID), 2004), http://pdf.usaid.gov/pdf_docs/PNADB219.pdf.

[2]S. R. Connors (private communication).

[3]"ghetto," (Merriam-Webster Dictionary Online, 2010), http://www.merriam-webster.com/dictionary/ghetto.

[4]J. Williams et al., Australia State of the Environment Report 2001: Biodiversity Theme, (CSIRO Publishing, Canberra, 2001), p. 195, http://www.environment.gov.au/soe/2001/publications/theme-reports/biodiversity/pubs/biodiversity.pdf.

[5]N. Gronewold, "One-Quarter of World's Population Lacks Electricity," (Scientific American Online: Greenwire, November 2009), http://www.scientificamerican.com/article.cfm?id=electricity-gap-developing-countries-energy-wood-charcoal&page=2.

[6]B. Dome, A. Dione, A. Baggini, and J. Manson, "Business plan for rolling out the Brazilian Paraisopolis slum Electrification Pilot programme in Sub Saharan Africa," (European Copper Institute (ECI), April 2009, unpublished).

[7]A. Tibaijuka, "Cities without slums," Our Planet 161, 12 (2005), http://www.ourplanet.com/imgversn/161/images/Our_Planet_16.1_english.pdf.

[8]I. Fried, "Photos: Inside Brazil's Slums," (CNET News, April 2008), http://news.cnet.com/2300-1042_3-6244980-3.html?tag=mncol.

[9]"Greenfreeze: A Revolution in Domestic Refrigeration," (Greenpeace, 1994), http://archive.greenpeace.org/ozone/greenfreeze/.

[10]"Transforming Electricity Consumers into Customers: Case Study of a Slum Electrification and Loss Reduction Project in Sao Paolo, Brazil," (USAID, February 2009), http://www.leonardo-energy.org/webfm_send/2766.

[11]"Powering and Empowering Development: Increasing Access to Electricity in Angola," (Academy for Educational Development, 2008), http://www.aed.org/Publications/upload/Powering_and_Empowering_Dev.pdf.

[12]H. De Keulenaer, "Electrifying slums in Brazil," (Leonardo Energy, May 2007), http://www.leonardo-energy.org/electrifying-slums-brazil.

[13]"History of Electric Co-ops," (National Rural Electric Cooperative Association, 2010), http://www.nreca.org/AboutUs/Co-op101/CoopHistory.htm.

[14]D.N. Nkwetta et al., "Electricity supply, irregularities, and the prospect for solar energy and energy sustainability in Sub-Saharan Africa," Journal of Renewable and Sustainable Energy 2, 023102 (2010), http://scitation.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=JRSEBH00000200000020231020000001&idtype=cvips&prog=normal&doi=10.1063/1.3289733.

[15]"Rural Electrification in Mexico with Renewable Energies," (Sustainable Energy Policy Concepts, 2003), http://www.ises.org/sepconew/Pages/RuralElMX/2.html.

[16]"Wind power and hybrid systems," (SunTechnics, 2008), http://www.suntechnics.ch/in/wind_hybrids.htm.