From açaí to access: distributed electrification in rural Brazil

Hisham Zerriffi
Liu Institute for Global Issues, Vancouver, Canada

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Abstract

Purpose – To rigorously examine success and failure in the use of small scale technologies for rural electrification.

Design/methodology/approach – Semi-structured primary field interviews plus secondary sources.

Findings – Business model differences and influence of institutions important are important for understanding success and failure in rural electrification and the contribution rural electrification can play in rural development.

Research limitations/implications – Data on the entire universe of distributed electrification efforts are unavailable. This highlights the need for better documentation of energy activities in rural areas.

Practical implications – The development of new policies to guide rural electrification towards more sustainable and development enhancing outcomes.

Originality/value – Prior studies have taken an *ad hoc* approach to study previous projects and suffer from case selection bias since their scope is limited in geography (one country, region or even village), technology (only PV or only wind or only renewables), or end-use (household electrification and productive uses). This study proposes a clear set of independent and dependent (as well as control) variables and looks across a range of cases to draw conclusions.

Keywords Energy supply systems, Brazil, Rural regions

Paper type Research paper

1. Introduction

Access to electricity is a basic indicator of development, potentially contributing to income generation, improved educational and health outcomes, gender equalization and a host of other social welfare improvements (Cabraal *et al.*, 2005; World Bank, 1996; International Energy Agency, 2004; Goldemberg and Johansson, 1995; WEC, 1999). While energy indicators were not included explicitly in the millennium development goals (MDGs), improved access to modern energy services, including electricity, is considered one of the enabling conditions underlying achievement of the MDGs. Electrification will be necessary for refrigeration of vaccines or lighting to improve evening study conditions (Modi *et al.*, 2006).

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The global electrification rate went from 49 percent in 1970 to 73 percent in 2000, resulting in 2.3 billion people gaining access during that time (International Energy Agency, 2002). This represents a massive effort on the part of governments, international donor agencies, utilities and other actors. However, the gap between electricity needs and current levels of electrification remains large. Currently, 1.6 billion people worldwide are unelectrified, primarily in rural areas. Even that figure, large as it is, does not address the electricity needs necessary to contribute to broader patterns of rural development since it only counts households and not income-generating activities.

Rural electrification is extremely challenging, however. Rural populations are widely dispersed and remote, making extension of the grid difficult, and any electrification option more expensive than in urban areas. Incomes are also generally quite low-making cost-recovery challenging. Brazil, the largest and most populous nation in South America, is no exception and at last count roughly 10-12 million people are without electricity[1]. This includes roughly 1.2 percent of urban households in 2002, but the bulk of the ten million live in rural regions, particularly in the Amazon region and the Northeast (up to 60 percent of rural households in some regions with a national average of 27 percent of rural households without electricity in 2002) (ESMAP, 2005). It is difficult to see how Brazil, can accomplish its goals of universal service without resorting to some form of decentralized electricity production. At the same time, distributed solutions face a number of institutional barriers that have either precluded their implementation or created conditions unfavorable to their success, even when they may be the best solution from a purely technical perspective.

This raises a number of questions about how distributed generation (DG) systems will play a role in rural electrification. How can DG systems be installed and run in ways that are financially sustainable and replicable and in a way that meets the needs of rural populations? What is the role of the institutional context in determining the nature of the DG solutions implemented and their success or failure? In order to understand how DG can contribute to the electrification of rural areas, it is necessary to conduct a structured study of past experiences. This paper reports on the history of distributed electrification efforts in Brazil, with a focus on the business models that have been used for distributed rural electrification, and the role that the institutional context has played in determining outcomes.

DG technologies ranging from diesel generators to solar home systems already have a long history in Brazil. Currently, distributed electrification in Brazil is dominated by the centralized utilities installing and operating distributed technologies in order to meet their regulated service mandates. This paper first examines the successes and failures of distributed rural electrification efforts in Brazil including a number of activities that have been outside of the utility system. The next section of the paper is a review of the rural electrification problem in general and the role that DG can play in solving the problem. Section 3 is a review of the methods used in this work on Brazil, which is also part of a larger study. The larger study looks across three very different institutional contexts (Brazil, Cambodia, and China) to examine the factors important for success and failure (Zerriffi, 2006). Examining multiple DG cases in each country over time and in more than one country provides variation in both the key business model variables and in the institutional context. With those two sections as background, the fourth section describes the institutional context for distributed electrification efforts in Brazil. Section 5 presents the results of the study. Section 6 highlights the role of DG in meeting the twin policy goals of universal service and cheap power in rural areas. It outlines problems with how these policy goals impact rural electrification efforts and the use of DG and makes policy recommendations regarding how rural electrification should be approached in order to aid in rural development and improve effectiveness of DG efforts. A concluding section summarizes the paper's results.

2. Rural electrification and distributed generation

Provision of electricity service worldwide has predominantly been through large centralized systems due to the economies of scale provided by ever larger generating plants and the (perceived or real) natural monopoly characteristics of transmission and distribution. Accompanying the technical centralization is institutional centralization, with control over the systems resting with a small number of organizations (both governmental and private). Similarly, the regulation of these systems also became centralized. Regulation has been limited to national or state level organizations or is implicit within the centralized utility itself. Even major restructuring efforts have retained the technological, and much of the institutional, centralization of the system (Haugland *et al.*, 1998; Mackerron and Pearson, 2000; Victor and Heller, 2006).

In many cases, this system has functioned relatively well. However, the economics of grid extension rely on spreading high costs over a maximized density of customers in a given region and a certain level of consumption. The rural electrification problem is a challenging one for the centralized utilities on purely technical and economic grounds. The populations are often remote, sometimes in difficult terrain, and often widely dispersed, making grid extension costs high. At the same time, rural income levels are not generally as high as in urban areas and consumption levels at the household level tend to be lower. Furthermore, centralized utilities in many countries simply do not have the managerial and financial resources to meet all rural electricity needs (Foley, 1992a). Even in those areas where the grid does reach, electricity is often sporadic and of low quality, making it difficult to use for productive purposes or for vital tasks like vaccine refrigeration.

Distributed power generation is attractive for rural electrification for a number of reasons[2]. For example, the low-population densities and low consumption of rural customers is well matched to the scalability and autonomous operation possibilities of distributed power[3]. Distributed power is able to provide power at levels and at times that are well-matched to rural customers. Finally, the possible set of organizational models is much greater with distributed power, including the possibility of decentralized local organizations (either private or public). This can potentially alleviate some of the high-transaction costs inherent in a centralized organization with a highly decentralized customer base (Hansen and Bower, 2003; Banerjee, 2006; Chaurey *et al.*, 2004).

While DG technologies may be the best (or only) option in many circumstances, it must be recognized that there are also disadvantages to their use. Many of these technologies are more expensive than grid-generated electricity on a per kW basis, and would not be competitive if the grid was eventually extended (or if existing grids were strengthened to provide reliable power) (ESMAP, 2000b, 2005). When combustion engines are used, there are limited pollution controls (if any), contributing to both local and global environmental problems. Depending on the institutional model that resulted in the DG installation, there may also be little or no support for operations and maintenance, leading to shortened technology lifetimes (Martinot *et al.*, 2002; Nieuwenhout *et al.*, 2001).

The use of distributed power sources for rural electrification is not new. In a limited way, distributed power generation has been used for decades. In the 1970s, a large effort was made by international donors to provide off-grid technologies for rural electrification as well as attempting to expand grids and solve other rural energy problems; those efforts have continued in one way or another to the present. In terms of the success of distributed power generation to provide rural electricity, the historical record is mixed at best (Barnett, 1990; Martinot, 2001; Martinot *et al.*, 2002). There have only been a few examples of successful projects that have been sustainable and/or replicated on a larger scale., like Kenya's photovoltaic market and China's small hydropower systems (Acker and Kammen, 1996; Pan *et al.*, 2006, Working Draft; Duke *et al.*, 2002).

Unfortunately, the existing literature on successes and failures in distributed electrification is only partially helpful for general policy-making. We can divide the literature into three broad categories. First, technology specific analyses focus on the opportunities (and sometimes the challenges) of using a particular technology (usually renewable) to meet rural electricity needs (Allderdice and Rogers, 2000; van Campen *et al.*, 2000; Li *et al.*, 2001). Second, project reports describe a particular activity, usually within a few years after implementation (and, again, usually renewable energy technologies). This category includes numerous village level-projects (technology X was installed in village Y and worked/failed), as well as reports on broader programs covering a larger region (Santos and Zilles, 2001). Finally, business success stories are a start towards filling a major gap in the literature, namely the need to understand why business models for distributed electrification succeed or fail. However, far too often this category overlaps with the first and what is reported is relevant only for a specific technology, such as photovoltaics (ESMAP, 2001).

What all these studies have in common is their *ad hoc* approach to studying a limited set of previous projects based on geography (one country, region or even village), technology (only PV or only wind or only renewables), or end-use (household electrification and productive uses) (Hurst, 1990; Fishbein, 2003; Etcheverry, 2003; Allderdice and Rogers, 2000; Erickson and Chapman, 1995; Martinot *et al.*, 2002). This study attempts to avoid systematic biases by not selecting or rejecting cases a priori on the basis of technology, end-use or outcome.

The other gap that this study fills is linking many of the institutional issues that are known to impact outcomes in rural electrification to a carefully constructed case-based analysis. Many of the individual case studies discussed above do include discussion of institutional issues such as regulations, electrification policies, access to financing, etc. However, for the same reasons as above, it is difficult to generalize because of their scope. On the other hand, there is prior literature that covers many of the institutional issues addressed in this research. The findings in this literature have been generalized from the secondary literature and from the author's experience (Foley, 1992b; Barnes and Floor, 1996; Reiche *et al.*, 2006; Barnett, 1990; Radulovic, 2005).

3. Study of business models for distributed electrification[4]

There is a universe of countries in which some form of distributed electrification has been attempted. From this universe of countries, we have chosen to focus on three: Brazil, Cambodia and China. These three countries have very different institutional environments (particularly in their regulatory and policy regimes) and different business models – in fact multiple business models within each. When combined across all three countries, there are roughly 20 different models and this is the sample analyzed in this overall study. We exploit the variation between the models in each country and the variation between the institutional contexts of the three countries in order to examine factors important for success and failure.

Based upon a review of the literature, discussed above, four independent variables were chosen to capture the important elements of the distributed rural electrification model (DREM): organizational form, technology choice, target customers and financial structure. The organizational form variable looks at whether the primary organization responsible is centralized or decentralized and whether it is governmental or non-governmental. The technology choice variable categorizes DREMs according to whether they use renewable versus non-renewable energy technologies and whether the system is a mini-grid or individual installations. The target customers variable is used to examine how models that electrify households perform differently than those that electrify productive activities or community structures. The financial structure variable provides information on how capital is obtained and how operational costs are covered.

Each DREM was assessed based on three main dependent variables: changes in electricity service, sustainability and replicability. changes in electricity service primarily measures the increase in electricity access as a result of the DREM. Secondary measurements are for the sufficiency and quality of the electricity supplied. Sustainability is primarily a measure of the ability of the DREM to cover its costs and provide functioning systems over a long period of time. Replicability is a measure of whether the particular characteristics of the DREM can be used to provide electricity services to new customers. Together, these three dependent variables measure the short and long-term impact of a DREM on the electricity supply situation.

Since, it is not feasible to gather data on every single DG initiative or project ever installed in the country, there are three potential sources of bias:

(1) Lack of information on older projects, particularly those that have failed. In some cases, it was possible to obtain limited information on these efforts through interviews. In those instances, they were not treated as full cases for the study, but this information was used to help support general conclusions drawn from the cases.

(2) Lack of information regarding smaller and less public efforts, such as independent diesel generators in the Amazon. Similar efforts to fill in some information about these distributed models were pursued as with the first case.

(3) In some cases, detailed information came only from the parties responsible for a particular electrification model. This could lead to potential bias in some of the results, though in all of these cases, there were both negative and positive assessments provided, indicating that there was no systematic bias towards presenting the information in an overly positive light.

As data were collected on the different cases and categorized into the dependent and independent variables, some of the relevant information did not fit into the existing variables. These data fell into two basic categories. Data relevant to the institutional context were added as control variables. The presence of subsidies for either capital costs or operating costs makes a large difference regarding the viability of a distributed electrification model. It improves the finances of the model (as long as the subsidy is sustainable) and makes other models less competitive. The level of capital and operating subsidies were given scores on a low-medium-high scale. In addition to subsidies, there was a need to categorize the policy and regulatory regimes more generally in order to capture the impact of the institutional context on the distributed electrification models. The policy and regulatory regimes were characterized as favorable, neutral or unfavorable.

Data relevant to the physical context were also included as control variables. We are particularly interested in the remoteness and the density of the population. Remoteness bears directly on the potential viability of grid extension and on the potential difficulties related to project management and operations and maintenance. The density of the population is relevant for the relative viability of the grid, micro-grids and individual installations.

Data for the study were collected through a combination of secondary sources, site visits and interviews. In particular, officials within relevant ministries and regulatory authorities were interviewed as well as donors, academics and representatives of non-profit organizations. This provided valuable information about the history of electrification efforts and the institutional context for rural electrification. Interviews and site visits were used where possible to collect information about specific distributed electrification efforts and to supplement information from secondary sources. The dependent variables used to assess the performance of the DREMs were scored on a high-medium-low scale according to a set of pre-specified criteria shown in Table I.

For example, the diffusion of solar home systems by the centralized utility, COELBA, is given high scores for access, sustainability and replicability. This program will diffuse roughly 30,000 solar home systems and will be the primary way in which COELBA meets the electricity needs of its customers it cannot reach by the grid, accounting for its high score on the access variable. Owing to the ability of COELBA to cross-subsidize its service and its obligations under the regulatory system, this model is given a high score on the sustainability parameter since the utility can reasonably be expected to continue its service. Replication of the solar home system program beyond the initial phase with expectations of full service to all households is evidence that replication has been widespread and so this variable is also scored as high. It should be noted that, in this example, the utility is able to take advantage of favorable policy and regulatory regimes and subsidies for capital (through government grants) and operating expenses (through cross-subsidies). This is reflected in the control variables, and it is therefore possible to see that this model's outcomes rely upon those favorable regimes and subsidies.

4. The institutional context for distributed electrification in Brazil

The use of distributed power generation in Brazil for rural electrification has to first be put in the larger context of the structure of the Brazilian electric power sector and

	High	Medium	Low
Electricity access	It is the dominant mode of service delivery in that area and has extended beyond the pilot phase	It has extended beyond the pilot phase but is not the dominant mode of service delivery	Occurs in a handful of communities
Sufficiency	Enough power is available to meet general demands and there is little or no exit from the system	Enough power is available to meet general demands but the system is run at full capacity and/or some portion of customers exit the system	Enough power is available only to meet basic demands (e.g. lighting and one low-consumption appliance in the case of households) even if customers require more
Quality	Outages approach those of the main grid utilities and power fluctuations and line voltage drops are not a major issue	Outages are higher than the main grid and power quality is lower but long outages (>1-2 days) and damage to equipment are rare	Frequent longer outages, high-voltage drops over mini-grid lines and damage to equipment is common
Sustainability[a]	Continued performance up to the expected lifetime of the technology is demonstrated or reasonably expected without major changes to the basic model	Continued performance up to half the expected lifetime of the technology is demonstrated or reasonably expected without major changes to the basic model	Failure to continue to deliver electricity beyond five years or major changes required to the model in order to continue electricity beyond five years
Replicability	Only marginal changes required to either the financial structure or institutional arrangements in order to replicate and evidence of actual replication	Some changes required but relatively adaptable	Significant changes would have to be made to the business model in order for it to be replicated. This can be the result of failure of the original model, reliance on specific financial resources that may not be widely available or reliance on institutional arrangements that are unique and difficult to change

Note: [a]The sustainability metric also includes a score of very low to account for those cases in which the DREM fails almost immediately (i.e. within two years after installation). These are generally cases where technology failure occurs quickly and the DREM is not able to provide for service

Table I.
Criteria used to score dependent variables

recent government programs and imperatives. The electricity industry in Brazil has undergone a series of significant institutional changes over the last century. A comprehensive review of this history is beyond the scope of this paper and has been covered by others (de Oliveira, 2003). However, it is worth noting that in the beginning it was the private sector that built, owned and operated the electricity system. By 1950, the installed generation was roughly equally owned by private and state interests. However, private ownership was static from 1935 until the most recent era of reforms in the mid-1990s. This shift from a private sector to state sector system was less the result of outright nationalization as the result of fiscal and other policies by the Brazilian Government that made investment in the electricity industry unattractive for private interests (de Oliveira, 2003).

By the time of the latest reform era, the Brazilian system consisted primarily of federally owned electricity assets, particularly the large hydropower plants and the transmission system, and state-level government utilities. The federal government owned a little over half of the generation (with the rest primarily in the hands of the states) but less than a quarter of the distribution was through federally owned utilities (while stxate utilities distributed roughly three quarters of the electricity). Eletrobrás was the federal holding company for electricity assets and the federal government divided the country into four regional suppliers (Chesf, Furnas, Eletrosul and Eletronorte). The system was regulated formally by the National Water and Electrical Power Department (DNAEE), though the finance ministry exercised a significant power over tariffs (for example, to ensure macro-economic stability). As noted above, tariffs were insufficient to recover investment costs. In order to maintain the legally mandated rates of return on investment, the difference was put into their balance sheet as the Conta de Resultados a Compensar, an amount that in theory could be recovered by tariffs at a later time (de Oliveira, 2003).

However, international trends in the electricity sector towards reform and the imbalance between investment costs and revenues led to a period of restructuring starting in the 1990s. Some of the distribution utilities were privatized, independent power producers were encouraged, and an independent regulator was established (*Agência Nacional de Energia Elétrica*, *ANEEL*). While some of the utilities were privatized, this did not change the highly centralized nature of the Brazilian electricity system. *ANEEL* oversees a system of monopoly service territories granted on a concession basis, much like in the USA. Concessionaires have rights (exclusivity in their service territory) and obligations (universal service and regulated tariffs).

At the same time, there was renewed interest in rural electrification for equity reasons, resulting in a number of new programs. Enshrined in the Brazilian constitution of 1988 are guarantees for basic needs and social solidarity and requirements for the government to provide, directly or indirectly, public services. It has also been argued that since electricity is required to meet those basic needs, it should also be considered as part of the constitutionally guaranteed services provided poorer populations in Brazil (Paz *et al.*, 2007). *ANEEL* established tariffs that reflect the notion that poorer populations (both rural and urban) should pay reduced tariffs (discussed further below). The tariff structure requires concessionaires to cross-subsidize their low-consuming customers (on the assumption that low consumption is correlated with low income) with higher tariffs for other consumers. In addition, special funds were established (even before the reform period and the latest constitution) to reduce national inequities in economic status. One is the *Reserva Geral de Garantia* (the RGG, established in 1977) which created a uniform tariff by transferring money from the lower cost and more profitable companies (in the South) to the higher cost companies serving lower income populations in the North. Another fund, the Global Reserve for Reversion (RGR), financed by a 3 percent levy on fixed assets, is intended to fund new construction and has been spent primarily on rural electrification.

A number of government programs have been put in place to improve the electrification situation in Brazil. The *Luz no Campo* program was aimed at extending the national grid system into adjoining areas that were unelectrified. The *Programa de Desenvolvimento Energético de Estados e Municipios* (*PRODEEM*), discussed further below, specifically targeted community structures such as schools for electrification. Owing to the remoteness of the communities for which *PRODEEM* was established, electrification was done through solar panels.

Until recently, however, the concessionaires did not make all the effort required to reach universal service, prompting legislative action and *ANEEL* to establish a 2015 deadline (*ANEEL*, 2003). As part of the larger rural welfare programs of the Lula Government, a law (*Luz Para Todos*, Light for All) was passed that provided financial incentives for utilities to achieve their universal access goals if they met more stringent targets (2008 instead of 2015) (O Governo de Brasil, 2003; Ministério De Minas E Energia, 2004)[5].

The explicit goal of the program is universal electrification with a fixed date to meet the program's objectives:

> Art. 1 – A National Program for Universalization and Use of Electrical Energy (*Luz Para Todos*) shall be instituted, destined to provide by the year 2008, electricity service to the portion of the population in rural areas of Brazil that still do not possess access to this public service (Author's translation).

The program provides funding to the Brazilian utilities to meet their regulatory obligations to serve everyone within their exclusive service territory. Universal service in this case means primarily households. This reflects the broader emphasis internationally, where the most used statistic used is the proportion of the population that is unelectrified.

The possibility of receiving funds for expansion rather than the unfunded mandate of *ANEEL* led the utilities to sign on to the basic bargain. (BR.IND, 2005; BR.ACAD.SB, 2005; BR.MME, 2005) They now have access to significant federal resources for connecting new customers (or building isolated or individual systems for households too far from the grid). Of the $2.4 billion estimated by the Ministry of Mines and Energy necessary for universal electrification, the federal government will provide 72 percent of the funds. This is primarily through the grants of the *Conta de Desenvolvimento Energético* (*CDE*) and RGR grants and loans (BR.MME, 2005)[6]. While it is becoming increasingly clear that this target will only be met in the more industrialized south, where the challenges are not as great, the government remains committed to the goal (BR.ACAD.AM, 2005; BR.ACAD.SP, 2005; BR.ANEEL, 2005; BR.DONOR, 2005; BR.MME, 2005). The *Luz Para Todos* fund alleviates one of the financial burdens utilities face in reaching rural customers, the high-capital costs. The difference between the low tariffs for rural customers and the high cost of service continue to be covered by other mechanisms, primarily different forms of cross-subsidization.

Tables II and III provide a summary of the major actors, laws, regulations and programs relevant to rural electrification in Brazil. The next section describes the distributed rural electrification efforts in Brazil by two very different sorts of actors. First are the centralized utilities, which have used DG technologies to meet their universal service obligations. The second sub-section outlines the large variety of programs that have been put in place to fill the gaps left by the centralized system.

Organization	Function	Comments
Agência Nacional de Energia Elétrica (*ANEEL*)	Regulation of all aspects of the electricity industry	Enforces conditions of exclusive service territories, technical requirements, tariffs for low-income consumers, etc.
Cooperatives	Cooperatives have been in place for a long time in Brazil and theoretically have the right to become concessionaires under *ANEEL* regulations	The technical requirements for becoming a concessionaire may cause some cooperatives to give up the independent electricity supply
Eletrobrás and subsidiaries	Government-owned holding company and subsidiaries in generation, transmission and distribution	Own utilities in the less profitable and more challenging rural areas of the north of Brazil, including the Amazon
Government distributors	Distribution of electricity to a concession area	Have exclusive service territories and obligations to serve as set by *ANEEL*. Even though three of the six federal distributors made money in 2004, federal distribution resulted in net losses to Eletrobrás
International donors	Funding of rural electrification efforts	Have been responsible for early failures in diffusing technology. Heavily involved in promoting restructuring in Brazil
Ministério de Minas e Energia	Oversees national energy programs, including the *Luz Para Todos* program for universal service	
Non-governmental organizations	Have been involved in a number of rural electrification projects	Facing stiff competition from utilities meeting their concession obligations, either because they are not official concessionaires or because their stand-alone systems cannot compete with the high subsidies of the centralized system
Private distributors	Distribution of electricity to a concession area	Have exclusive service territories and obligations to serve as set by *ANEEL*
Private enterprises	Have provided electricity in areas that the utilities have not served (e.g. diesel mini-grid entrepreneurs)	Illegal under *ANEEL* regulations and charge tariffs that do not meet *ANEEL*'s requirements

Table II.
Major actors in Brazil's rural electrification

5. Distributed electrification models in Brazil

The distributed electrification efforts in Brazil can be divided into two groups for purpose of analysis. The dominant group comprises the highly centralized efforts of the utilities and the central government (often working through the utilities). Their dominance is the result not only of the regulatory system but also of the tariff structure

Program/subsidy	Function	Comments
ANEEL Resolution 223 (2003)	Fixes deadlines for concessionaires to meet their universal service obligations	Deadlines range from 2006 to 2015 depending on the current level of electrification
CCC	Conta de Consumo de Combustiveis. To provide subsidized diesel, particularly in the Amazon	Makes diesel competitive for those with access to the CCC. Not all consumers qualify
Decreto 4.873 (2003) and Portaria No. 447 (2004)	Established the *Luz Para Todos* universal electrification program that provides incentives for utilities to meet their obligations by 2008	Utilities have flexibility to meet obligations via both grid extension and centrally managed DG. Customers do not pay for installation and their tariffs are set by *ANEEL*
Lei 10.438 (2002)	Establishes Programa de Incentivo às Fontes Alternativas de Energia Elétrica (PROINFA) for promotion of renewables and the *CDE* for funding universal electrification	It also sets the limits for who is eligible for reduced tariffs
Lei 10.762 (2003)	Makes technical modifications to earlier laws, including 10.438	
Low-income tariffs	To reduce the financial burden on low-income families of having electricity service. Tariffs are set according to consumption level per household with households below 30 kWh/month paying a highly reduced rate (35 percent), those between 30 and 100 kWh paying 60 percent and those between 100 kWh and a regional limit ($\sim$240 kWh/month) paying 90 percent of the residential tariff	The difference is made up through cross-subsidies (private utilities) or by passing losses onto the federal holding company (government utilities)
Luz No Campo	A grid-based universal electrification program	Did increase electrification rates but was not designed to meet the needs of the most remote populations
PRODEEM	Programa de Desenvolvimento Energético de Estados e Municipios. Promoted the use of renewables for community structures such as schools and clinics	Has had mixed success in being able to install and, more importantly, maintain systems
RGG	Reserva Geral de Garantia	Forced a uniformization of tariffs between more expensive northern utilities and more profitable southern utilities
RGR	Reserva Global de Reversão. A levy on fixed assets to finance continued construction in the electricity sector	Money collected spent primarily on rural electrification

Table III.
Major legal documents, government programs and subsidies relevant to rural electrification

and of the money flows from the government. They are centralized in terms of organization, but have variation in the other business model factors (e.g. technology, target customers and financing).

The deficiencies in the centralized model, particularly the lack of incentives until recently to fully serve the consumers within their service territory, have led to the development of a number of alternative models. These models are not able to access many of the same resources as the centralized utilities (either in terms of government funding or in terms of a diverse consumer base that can be used for cross-subsidization) and so they remain on the periphery of the distributed electrification effort. However, there is much to be learned concerning the possibility of rural electricity markets and the contributions that electricity can play to larger development efforts.

The next two sections discuss the specific distributed electrification models examined in this study. First are the centralized models operated by the utilities and with government support. Second are the alternative models.

5.1 Centralized organizations delivering distributed power

The use of DG in Brazil for rural electrification is dominated by the installation of diesel mini-grids and solar home systems by centralized utilities. This centralized utility model is a direct result of the regulations governing the electricity sector which mandate exclusive service territories for concessionaires and low tariffs for lower income consumers. The policies of the federal government have reinforced the centralized utility model through the *Luz Para Todos* program.

Companies like CEAM are government-owned utilities. CEAM serves the rural areas of Amazonia and is installing more mini-grids based on diesel generation to serve its rural customers. The capacity of the CEAM grids allow for basic household electrification, but not much else. As the official concessionaire, CEAM is able to utilize the *Luz Para Todos* fund plus the CCC diesel subsidy to keep costs down. However, since all of its customers are rural and lower income, CEAM also relies on its status as a government utility, part of the Eletrobrás group, which allows it to run a deficit (BR.SITE.AQ, 2005). CEAM's losses in 2004 (before taxes, interest, depreciation and amortization) were R$ 71 million (approximately $35 million US) (ELETROBRÁS, 2005).

Others like COELBA, in Bahia, are private utilities operating under a concession agreement with the federal government. Like other utilities, COELBA is relying primarily on extending their grid wherever possible (the lowest cost option for most of their customers) but using solar home systems to provide basic electricity services for their most remote and dispersed customers. These solar home systems are installed and maintained by CEAM and customers pay a reduced tariff similar to that paid by low-income grid-connected customers. The focus, again, is on household electrification. Like CEAM, they can utilize *Luz Para Todos* funds for construction. However, COELBA is a privately owned utility and does not have a higher level government holding company to absorb the losses. What it does have is a more diverse mix of customers and it is using richer customers to cross-subsidize its poorer customers, including those receiving solar home systems (BR.IND, 2005) (Table IV).

This is not to say that the utilities did not undertake any action prior to the *Luz Para Todos* program. The utility of Minas Gerais, CEMIG, undertook a rural electrification

		Utility diesel	Utility SHS	*PRODEEM*
DREM parameters	Organization	Centralized utility	Centralized utility	Central government
	Target customers	Villages	Households	Community structures
	Technology	Diesel mini-grid	Solar home system	PV
	Financial: capital	Grants/loans/soft budget	Grants/loans/equity	Government program
	Financial: O&M	Tariffs/cross-subsidy/soft budget	Tariffs/cross-subsidy	No O&M recovery
Control variables	Capital cost subsidies	High	High	High
	Operating cost subsidies	High	High	Low
	Customer density	Medium	Low	Medium
	Customer remoteness	High	High	High
	Policy regime	Favorable	Favorable	Favorable
	Regulatory regime	Favorable	Favorable	Favorable
Outcomes	Access	High	High	High
	Sufficiency	Medium	Low	High
	Quality	High	High	
	Sustainability	High	High	Low
	Replicability	High	High	Low
Notes on institutional factors	Policy measures	*Luz Para Todos* providing significant funds	*Luz Para Todos* providing significant funds	Replicable as long as gov. willing to continue to fund
	Regulatory measures	Regulatory requirements forcing electrification	Regulatory requirements forcing electrification	
		Subsidies allow for high sustainability and replicability	Subsidies allow for high sustainability and replicability	
	Other	Subsidies and soft-budget constraints for CEAM make it affordable	Subsidies make it affordable	

Sources: Sources cited in main text and BR.ACAD.AM (2005), BR.ACAD.SP (2005), BR.ANEEL (2005), BR.DONOR (2005), Correia *et al.* (2002), ESMAP (2000a, 2005), Gaube (2002), Goldemberg *et al.* (2004), GTON (2006), Winrock International Brazil (2002) and BR.DONOR.INT (2005)

Table IV.
Summary table for Brazilian DREMs (centralized organizations)

program that included the use of PV. The program had components for electrifying community structures, schools and households. For the household program, CEMIG covered nearly two thirds of the capital cost and the municipality within which the community was located would cover the other third. Households had to pay a monthly flat fee which was sufficient to cover eventual battery replacement, but not enough to cover all operations and maintenance, which CEMIG ended up paying for. As of 2001, CEMIG had fallen short of its original goals. Between 1995 and 2001, 450 solar home systems were installed of the estimated 4,700 expected. CEMIG also found itself paying more than its anticipated share of the capital costs due to poor municipal finances.

The program was switched to a consumption-based tariff on par with its grid customers (Diniz *et al.*, 1998, 2002).

The *PRODEEM* program established in 1994 used PV systems to electrify rural communal structures such as schools, clinics, etc. Systems were given to communities and little provision was made for operations and maintenance. While a large number of systems were installed over the six phases of the program between 1994 and 2002, *PRODEEM* was also plagued with a number of problems. Some were due to poor equipment, but many were also due to poorly chosen equipment (e.g. undersized inverters) or institutional problems. The result is that an unknown number of the *PRODEEM* installations are no longer working. One review sampled a small number of units (79 out of the 8,700 installed at the time) and found upwards of 50 percent not working (ESMAP, 2005; Galdino and Lima, 2002).

5.2 Alternatives to the centralized model

Alternative models have been limited in their impact on rural electrification in Brazil. They cannot compete directly with the centralized utilities both because of the legal mandate and because of the tariff structure and subsidy system to keep rural prices low. The recent expansion of the centralized system as the result of the *Luz Para Todos* program calls into question the role these alternative models can play in future rural electrification efforts. To a certain degree, the Brazilian Government has recognized that the focus of the centralized utilities on basic household electrification is limited and started to develop integrated action plans to meet more general economic development needs. These action plans would utilize more distributed actors rather than the centralized utilities.

Table V provides a summary of the relevant characteristics and the outcomes of some alternative distributed electrification models in Brazil. A number of distributed electrification efforts are not included in these tables such as the private diesel generators, cooperatives and pilot projects to use various biomass sources (such as açaí) in gasification systems. However, to the possible extent, information from these other cases, primarily based on interviews, was brought to bear in drawing the broader conclusions regarding distributed electrification in Brazil.

In the absence of action by the centralized utilities until recently, a number of alternative models for using DG technology have arisen in Brazil's rural areas. One NGO, *Instituto para o Desenvolvimento de Energias Alternativas e da Auto Sustentabilidade* (*IDEAAS*), has established a fee for service model to provide solar home systems in conjunction with its sister organization, a for-profit company. Customers pay an installation fee and a flat monthly fee (varying depending on the capacity of the system) in return for service. A combination of loans and grants are used to obtain capital. A few hundred systems have been installed, but financial sustainability has not yet been achieved (a minimum of 4,000 units would have to be installed). The recent push by the centralized utilities is causing *IDEAAS* to consider moving its focus to the northeast of Brazil where more people remain unserved and projections are that the utilities will not meet their deadlines of 2008. They are also looking at ways to partner with the utilities. The model would appear to be both sustainable and replicable in the absence of utility competition, but the costs limit their customer base to richer rural households (Mugica, n.d., BR.DONOR.INT, 2005).

		Brasus	*IDEAAS* SHS	SBC
DREM parameters	Organization	NGO plus regional coalition	NGO – for profit partnership	Entrepreneur plus NGO
	Target customers	Productive activities plus others	Richer households	Households
	Technology	Varies	Solar home system	Solar battery charging station
	Financial: capital	Loans	Loans/grants – installation fee	
	Financial: O&M		Monthly fee	Fees
Control variables	Capital cost subsidies	Low	Low	Low
	Operating cost subsidies	None	Low	None
	Density of customers	N/A	Low	Medium
	Remoteness of customers	High	High	High
	Policy regime	Neutral	Neutral	Neutral
	Regulatory regime	Unfavorable	Unfavorable	Unfavorable
Outcomes	Access	Low	Low	Low
	Sufficiency	High	Medium	Low
	Quality		High	Low
	Sustainability	High	High	Low
	Replicability	High	Medium	Low
Notes on institutional factors	Policy measures	Integrated action plans of MME envision partnering with NGOs on productive activities	LPT reducing incentive for individuals to obtain SHS since connection is free under LPT	
	Regulatory measures		Universalization requirements on utilities bringing them into competition with *IDEAAS*	
	Other			Frequent recharging Expensive

Sources: Sources cited in main text and BR.ACAD.AM (2005), BR.ACAD.SP (2005), BR.ANEEL (2005), BR.DONOR (2005), Correia *et al.* (2002), ESMAP (2000a, 2005), Gaube (2002), Goldemberg *et al.* (2004), GTON (2006), Winrock International Brazil (2002) and BR.DONOR.INT (2005)

Table V.
Summary table for Brazilian DREMs (alternative models)

Another NGO, Brasus, is focused on providing renewable energy technologies to rural productive consumers and establishing a sustainable market for such technologies through regional market managers. Capital, primarily from international donors, is used to set up a revolving fund and loans, carefully screened for credit-worthiness, are provided to the rural producers. The focus on productive activities (particularly, agricultural processing) increases Brasus' sustainability and also makes it less susceptible to competition from the utilities' expansion plans since many of those are focused on serving households (BRASUS, 2005).

Another entrepreneur-based model was based on solar battery charging stations. This project by an international donor used local entrepreneurs to run the stations. However, this model failed as customer dissatisfaction with the service rose over time. Customers complained about the need to bring their batteries to the station, the fact that battery life decreased quickly (necessitating more frequent visits and a rise in their monthly expenses), and accused the entrepreneurs at times of favoritism in handing out batteries (Santos and Zilles, 2001)[7].

Models based on local entrepreneurs have also been attempted. Within CEAM's service territory in the Amazon, numerous local entrepreneurs have installed small diesel generators to serve their and their neighbors basic electricity needs. Unfortunately, little data exist on these installations as they are outside the formal regulatory and legal system. However, a survey of 100 communities done by Ministério de Minas e Energia for CEAM found that 95 had a diesel generator (BR.MME, 2005). Indications are that costs of electricity are high, service is only in the evening and quality is likely low. One system in Nossa Senhora de Gracas in Amazonia had monthly charges that would be equivalent to 25-50 c/kWh (depending on usage) (BR.SITE.NSG, 2005). It would appear likely that many of the elements of this DREM are similar to the rural electricity entrepreneurs operating diesel mini-grids in Cambodia, which have been studied in greater detail.

6. Institutional change

The statistic most often used, including in Brazil, to measure progress in rural electrification is the number of households (or people) with access to electricity. As noted above, there are currently roughly ten million people in Brazil that do not have access to electricity.

Brazil's official rural electrification system has three main characteristics as a result of the regulatory regime and policies of the central government:

(1) Exclusive service territories for the utilities with a requirement for utilities to provide electricity to all consumers within their territory.
(2) Subsidies by the central government to utilities for capital costs under the *Luz Para Todos* program.
(3) Mandated low tariffs for low income and rural customers.

The focus of *Luz Para Todos* on household electrification can be seen in COELBA's PV program, which it is using to meet its obligations in the more remote regions of Bahia. The PV systems are for households only and there is no programmatic goal to include other customers or to provide more than basic household electrification (BR.IND, 2005). Even in the Amazon, diesel mini-grids are under-sized for inclusion of productive activities. For example, in Aquidabam, the diesel generator owned and operated by the central utility provides enough electricity for households, community structures, and a few stores. However, even then the system is unable to meet all the demand. Refrigeration for the local agricultural product, which would improve the community's ability to get its product to market, cannot be met, leading to an outside project for a biomass gasification system (BR.SITE.AQ, 2005).

Previous centralized programs, such as the *PRODEEM*, have had a focus on community structures, such as schools or health clinics rather than households. If sustained, electrification of these services can clearly impact human welfare in rural areas. The argument has been made that even improvements in education and health can be considered "productive" uses of electricity (Cabraal *et al.*, 2005). However, in terms of contributing to improved economic opportunities, programs like *PRODEEM* do not have a direct effect.

The second and third planks of governmental rural electrification efforts in Brazil establish a goal of price equity between rural and urban areas. In theory, under this system, poor rural (and urban) consumers pay tariffs that are commensurate with their much lower incomes[8]. The tariffs charged to rural customers are significantly below what is required for cost recovery, even accounting for the subsidies for capital costs. In order to be able to charge such low tariffs, the privatized utilities charge their urban customers higher tariffs and cross-subsidize the rural consumers (e.g. COELBA in the state of Bahia). The utilities still owned by government holding companies (such as those owned by Eletronorte) have soft budget constraints that allow them to show losses. These losses are covered by Eletronorte's other business units. In effect, this implies a cross-subsidy by the customers of those other business units, primarily the privatized utilities. In the one case, cross-subsidies are internal to the business. In the other, the cross-subsidy is shifted out of the distributed electrification business.

Along with the exclusive service territory regulations, the mandated low tariffs for rural customers create problems for alternative distributed models. Even if the regulations were changed to allow independent mini-grids to operate in rural areas, the customer base would not allow cross-subsidization and it would be impossible to charge the low tariffs mandated by the regulation. For those distributed models based upon sales or rentals of individual units (such as solar home systems), there is no prohibition against those businesses. However, as with the other alternative models, the incentives to purchase such systems are affected by the expansion of the utility system at little cost to the consumer.

The impact of the twin policies of universal service and rural/urban equity is shown in Figure 1. These policy priorities result in a focus on rural households (the easiest and most consistently used measure of rural electricity service) and low prices. This creates a situation in which costs are extremely high but the revenues gained by legal actors in the system are low. This is combined with a regulatory history favoring centralized utilities that are now the only ones that can access significant government funding or have other mechanisms to correct the fiscal imbalance. Alternative models cannot compete in areas where the central utilities are active (which, in theory, should be everywhere). In the case of private mini-grids, they cannot recoup their expenses under a regulated tariff regime which does not cover costs, and they are illegal since they violate the exclusive service territories of the utilities. In the case of solar home systems, the technology is being sold or leased and so they are, arguably, not in violation of either the exclusive territory or the tariff provisions of the regulations. However, they cannot compete on price with the highly subsidized utility system.

There are a number of policy impacts that result from this emphasis on expansion of the centralized system. On the positive side, there is a rapid expansion of basic household electrification and the low prices reduce the financial burden on low-income households. However, the sustainability of this expansion is entirely dependent upon

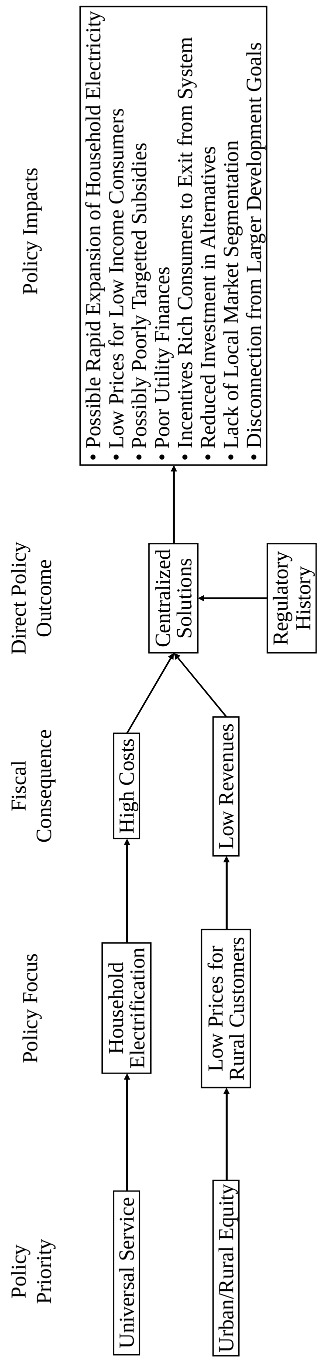

Figure 1.
Impact of policies for universal service and price equity between urban and rural consumers

continuing subsidies. It leads to poor utility finances and possible exit from the utility system by larger urban consumers (such as industrial firms) if their prices get too high (as has happened in India). It also means a reduced investment in some alternative models as everything, including government funds, are funneled through the utilities. It also means that local market segmentation cannot be exploited and niche markets are not served adequately. Finally, it also means that there is a disconnect between the electrification effort and larger development goals since there is little or no emphasis placed on income-generating activities or on community level services.

It is difficult to see how broader development goals can be met without an expanded role for locally implemented DG options, including private or semi-private solutions. This will require a shift in priories in two areas:

(1) *Rural development*. The focus on households marginalizes the need for electricity as an input into the rural development process. Making rural development a priority in addition to household electrification would increase electricity supply to productive activities (which also changes the economics of distributed rural electrification).

(2) *"Affordable" power*. The standard of keeping rural prices at or below urban prices creates barriers towards more distributed solutions and often relies on unsustainable subsidies. A shift towards improving affordability while still preserving the market segmentation that distributed systems can create would help meet the various rural electricity needs and improve the financial viability of rural electrification.

The impact of these policy shifts can be seen in Figure 2. In order to implement these policy shifts, there are a number of specific changes that need to be made, primarily to change the institutional context and incentive structure of the Brazilian rural electrification program. Changes need to be made primarily in three areas:

(1) A revision of the regulatory system to allow for alternative actors to participate legally and fully in solving the rural electrification problem.

(2) An expansion of the scope of the *Luz Para Todos* and the financial support it offers, along with other changes that would provide a more level playing field for distributed rural electrification.

(3) A change in the tariff structure. While this is part of the regulatory system, it is sufficiently important and complex that it needs to be treated separately.

The need for new regulatory arrangements for distributed electrification is paramount. These regulations must take into account the particular nature of the demand in rural areas and the technologies being used to meet that demand as well as the actors involved. Regulations must provide flexibility and be simple enough so as to not burden small actors (Reiche *et al.*, 2006). In particular, if distributed electrification models that currently contravene regulatory statutes (particularly, mini-grid models) are to be formalized, there must be provision made for the type of service they can provide. Holding them to the same technical standards as large grids is not feasible. Cambodia's regulation allowing for access that is less than 24 hours per day is one good example. However, the regulatory system is changed, there must be some stability in the policies so that long-term decisions and plans can be made.

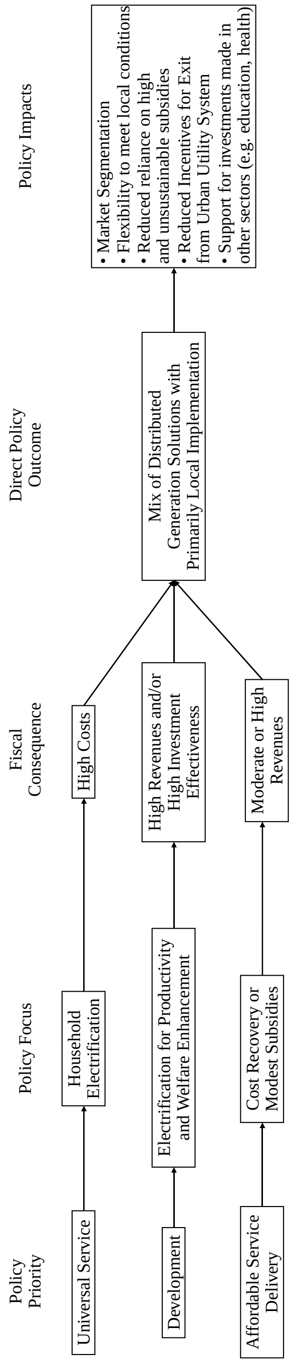

Figure 2.
Impact of revised policy priorities

The regulatory system must remain flexible in order to deal with unexpected outcomes, but the overall policies regarding rural electrification should ensure a role for the variety of actors that can contribute to the rural electrification problem over the long term.

Coupled with these changes in regulations, the *Luz Para Todos* funds have to be made available to a wider variety of actors, not just the centralized utilities. This will allow smaller actors to implement projects. At the same time, the integrated action plans that the ministry is implementing to expand the focus of the program beyond households must be strengthened and expanded. There are a number of other financial mechanisms that the Brazilian Government should explore in order to aid in the financial viability of rural electricity efforts. Favorable tax regimes can be put in place for specific technologies and/or for enterprises serving rural communities. Another would be in the area of international trade. Import tariffs for key distributed rural electrification technologies must be kept at a low-enough rate to avoid increasing the costs of rural electrification. Similarly, international donor programs must be geared not towards providing particular technologies, but towards creating access to resources and supporting efforts to create markets.

Arguably the most difficult problem is the one of tariffs. As long as tariffs are kept significantly below cost and cross subsidized via richer consumers, only the centralized utilities will be able to meet rural electricity needs since others cannot compete on price even if they are allowed legal status. Raising the tariffs to cover costs is one possibility. The theoretical literature which, supported by empirical evidence, indicates that supporting consumption rather than access often leads to negative results (Beato, 2000; Barnes and Halpern, 2000; UNEP, 2002). However, it is also recognized that lifeline rates are often necessary in order to account for the low ability to pay among some members of the population. The negative impacts of cross-subsidies also depend greatly upon how they are implemented and the relationship between the tariffs, marginal cost, average cost and avoided costs (Beato, 2000).

The implication of eliminating consumption subsidies entirely is that rural residents may be served with electricity that is expensive and/or of low quality and only for certain hours of the day. Some may not be able to pay those prices and be excluded from service. However, this would not address the equity concerns within Brazil that led to the current subsidy program and it could be politically quite difficult to remove such subsidies. Some form of lifeline subsidy would be needed at minimum. There are conditions under which cross-subsidies could be implemented while minimizing the economic damage. However, new transfer mechanisms would be needed that account for the political need for subsidies, the economic rationale for subsidies for those in need, and that do not preclude certain models from participating. This would be a continuation of the consumption subsidy, which means targeting of the subsidy will be important and without further study it is impossible to tell whether current subsidy levels and beneficiaries would change.

Transfers could occur through one of two channels. The first option would be to provide subsidies directly to the end-users. In this case, subsidies could be provided for energy in general, as has been suggested in South Africa. The advantage of an energy subsidy rather than an electricity subsidy is that it allows the consumer to make decisions based upon their energy needs and the availability of different options for meeting those needs. A more detailed examination of this option is necessary and would look at options to tie administration of this program (and qualification tests) to other social welfare programs already being implemented in rural areas of Brazil. This is already done for those consuming between 80 and 200 kWh per month[9]. One advantage of direct subsidies is that it would remove what is essentially a societal and political decision from affecting the functioning of the electric power system. This would free actors within the electricity system to make business decisions based on recovering their costs from end-users and compete on price as well as other factors. At the same time, those at the lowest end of the income scale would not lose the assistance they need to afford basic electrification.

The second option would be to create transfers among the electricity service providers, either directly or via the government. This could include partnerships among small actors such as NGOs, cooperatives and small entrepreneurs and the utilities within a regulated concession model. The possibility for such arrangements does exist within the Brazilian regulatory system. A concessionaire (the utility) can allow a permissionaire (e.g. a cooperative) to operate within its territories. However, the regulatory burdens for doing so are quite high, and it does not solve the cost-recovery problem, only the problem of the exclusive service territory. This has made it an unpopular option. A mechanism to allow smaller actors to access cross-subsidization funds that come from consumers of urban utilities would also be necessary. Such transfer payment systems have not been attempted to my knowledge and a host of questions would have to be answered regarding how it would be arranged and protected from capture.

Both alternatives would also imply that all players, down to the smallest ones, would be regulated entities raising problems of the transaction costs for both parties. Regulators in the electricity sector are not used to having to deal with a large number of small regulated entities. Similarly, license applications and other regulatory transactions would have be kept minimized and simple in order to these small actors to be able to participate in the system. However, if such a simplified system could be put in place, it could benefit all involved. The large utilities could concentrate their manpower and resources on serving the more densely populated areas through the grid system. Smaller actors could participate fully without worrying about operating illegally or being undercut by the large utilities. Communities and individuals could opt for electrification options that are best suited to their needs without losing the lifeline subsidies. Finally, governments could meet their desired electrification targets while also supporting broader rural development goals (Zerriffi, 2006). However, such a scheme has not been attempted and a number of pilot projects would have to be implemented. Unlike many prior pilot projects, which were designed to test suitability of a technology, these pilots would test the suitability of new institutional arrangements[10].

7. Conclusions

The regulations governing the Brazilian electricity system mandate that the large centralized utilities serve all customers within their exclusive service territory at rates designed to minimize economic hardship on lower income consumers.

The Brazilian experience with distributed rural electrification shows the power of centralized action coupled with relatively high subsidies. However, while this model is sustainable and replicable within Brazil at the moment, it does require continued central government support through the full phase of the expansion. It also requires a viable tariff structure that allows cross-subsidization with full cost recovery and at tariffs for the subsidizers that does not cause widespread exit from the system. One does not have to look hard for examples in which this type of cross-subsidizing system suffers from both problems (e.g. many Indian utilities).

This combination of high costs and low revenues without either incentives or consequences led most utilities to move slowly to meet their universal service obligations. As with the other countries included in the larger study, the absence of strong central support to force widespread electrification left open a gap for alternative electrification models (e.g. private diesel operators, cooperatives, NGO providing alternative energies) to meet the needs of different consumers. In the absence of financial support from the central government, successful models have had to meet requirements for sound financial sustainability in other ways. These independent efforts serve customers that exhibit the following characteristics:

- Productive activities or other customers with higher consumption are included in the customer mix (e.g. coops and NGO projects in Brazil).
- Relatively wealthier (e.g. PV customers)[11].
- Willingness to pay very high prices for very low consumption (e.g. unlicensed diesel genset customers).

In contrast to the centralized utility model, these alternative models sometimes go beyond basic electrification. Some are focused on providing electricity to productive activities in order to improve economic output and development (e.g. BRASUS). Others remain focused on households (e.g. *IDEAAS*), but allow for higher levels of electricity consumption than the basic levels provided by the utilities and are decentralized in both technology and organization.

New incentives are expanding the utility's geographic reach. However, the focus is on basic household electrification and tariffs have been kept artificially low, necessitating substantial ongoing subsidies. The incentives and the hard deadlines of the *Luz Para Todos* (even if they are delayed) will create problems for both existing and new models that may have advantages over the long-term and serve needs not being met by the centralized utilities.

The role of centralized actors should be more indirect than it has sometimes been in the past. Modest subsidies designed to spur technology development, favorable policies such as reduced taxes, regulations that protect and do not discriminate against distributed generators, and new institutional structures that preserve markets while protecting low-income consumers from highprices are all ways in which governments can help foster and promote rural electrification efforts for the most remote populations.

Notes

1. Brazil's total population in 2000 was 170 million, of which 123 million were in urban areas.
2. There is, unfortunately, no agreed upon definition of DG. Definitions have tended to be highly context dependent and focus on one or more particular characteristic of either the technology or its use (for a detailed discussion of how to define DG, see Pepermans *et al.* (2005) and Ackermann *et al.* (2001)). For the purposes of this study, generation is considered

to "distributed" when the power it generates is used primarily within the local distribution network (or by a single end-user).

3. While rural consumption is relatively low, its addition right at the time of peak power demand on the system can force the utility to run their more expensive generating units more often or even to invest in new peaking generation. This can significantly raise the cost of supplying rural customers (Howells *et al.*, 2006).
4. A more detailed description of the study methodology is in a forthcoming manuscript (Zerriffi, 2006).
5. Importantly, this is done at no cost to the consumer. The concessionaire can charge regulated tariffs, but cannot charge for connection under *Luz Para Todos*.
6. At 3 R$/US$.
7. Unlike other battery charging schemes, in this one, the customer did not own a specific battery, but would come and exchange their battery for another one, thereby eliminating the need to come back and pick up their battery. However, different users had different usage patterns and over time battery performance began to vary widely.
8. The situation is complicated by the fact that qualification for the low tariff is based not on income but on consumption. Low-consuming households are assumed to be also low-income households. There are no corrections made for various factors that could skew the correlation between consumption and income (such as household size).
9. Those consuming less than 80 kWh per month automatically get the reduced rates. Those between 80 and 200 can get a reduced rate if they are on the rolls of the social assistance programs that deliver other services.
10. Some form of backstop guarantee would be necessary to ensure that communities would continue to receive electricity even if the new institutional arrangement failed. The program would also have to be implemented in a way to maintains the obligations for universal service that the Brazilian population has come to expect. Utilities would not be let completely off the hook if other actors were not ready to move in and take their place.
11. These are customers that are at the top of the base of the pyramid. The base of the pyramid, a term covering the vast majority of the population that is usually ignored by commercial enterprises due to assumptions of their low-buying power, has become a powerful organizing idea for creating new opportunities to make money while solving societal problems and meeting environmental goals (see, for example, Hart, 2005).

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Corresponding author
Hisham Zerriffi can be contacted at: hisham.zerriffi@ubc.ca