Achieving Universal Access to Electricity through Decentralized Renewable Energy Technologies in Minas Gerais, Brazil

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Approved 16/03/2012
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Abstract

Brazil started the Luz Para Todos (Light for all - LPT) program in 2003 aiming at universalization of electricity access in the country. The program uses three technological solutions to reach this goal: grid extension, decentralized power generation with isolated grids and stand-alone systems. This master thesis analyzes the role of decentralized renewable energy technologies in the Luz Para Todos program in the state of Minas Gerais. The factors that lead to the use of such technologies in the specific case of CEMIG (Energy Company of Minas Gerais) are considered. The study showed that regulatory framework and energy policy mechanisms are the most important determinants of the method of attendance in rural electrification. It is concluded that decentralized renewable energy technologies emerge as a strong alternative when it is not technologically and/or financially feasible to extend the grid.

Key words: rural electrification; luz para todos; light for all; renewable energies
Acknowledgements

I would like to thank all people who have helped and supported me during this study.

I greatly appreciate the support by my supervisor María F. Gómez. Without her guidance, support and encouragement, this thesis would not have been completed.

Many thanks to Prof. Semida Silveira for her intellectual support and valuable efforts to arrange the exchange period in Brazil. I am also grateful to Dr. Wadaed Uturbey da Costa for supervising my thesis in Brazil and facilitating my exchange period.

Finally, I would like to thank my family and friends for their continuous support.
Abbreviations and Nomenclature

ACL  Ambiente de Contratação Livre (Free contracting environment)
ACR  Ambiente de Contratação Regulada (Regulated Contracting Environment)
ANEEL  Agência Nacional de Energia Elétrica (Brazilian Electricity Regulatory Agency)
CCC  Conta de Consumo de Combustível (Fuel Consumption Account)
CDE  Conta de Desenvolvimento Energético (Energy Development Account)
CEMIG  Companhia Energética de Minas Gerais (Energy Company of Minas Gerais)
CGE  Comitê Gestor Estadual (State Management Committee)
CGN  Comitê Gestor Nacional (National Management Committee)
CNU  Comissão Nacional de Universalização (National Universalization Commission)
COELBA  Companhia de Eletricidade do Estado da Bahia (Electricity Company of the state of Bahia)
COPASA  Companhia de Saneamento de Minas Gerais (Sanitation Company of Minas Gerais)
CRC  Conta de Resultados a Compensar (Results Compensation Account)
DIC  Duração de Interrupção por Unidade Consumidora (Duration of Interruption per Consumer Unit)
GW  Gigawatts
GWh  Gigawatt hours
HDI  Human Development Index
IBGE  Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics)
IEA  International Energy Agency
kW  Kilowatt
kWh  Kilowatt hours
LPT  Luz Para Todos (Light for all)
MG  Minas Gerais
MME  Ministry of Mines and Energy
MW  Megawatt
MWh  Megawatt hours
PRODEEM  Programa de Desenvolvimento Energético de Estados e Municipios (Program for Energy Development of States and Municipalities)
PRONAF  Programa Nacional de Fortalecimento da Agricultura Familiar (National Program for Strengthening Family Farming)
PUC  Pontifícia Universidade Católica (Pontifical Catholic University)
PV  Photovoltaic
RGR  Reserva Global de Reversão (Global Reverse Fund)
SIGFI  Sistema Individual de Geração de Energia Elétrica com Fonte Intermitente (Individual System for Generation of Electrical Energy with Intermittent Source)
UNDP  United Nations Development Programme
Wp  Watt-peak
€  Euro - European Union Currency
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Electricity is the driving force of modern life. There were 2 million households in Brazil, without access to this basic service in 2003 (MME, 2011a). Electrical exclusion is predominantly observed in rural areas of the country, where Human Development Indexes are low. The access to electricity is considered fundamental in achieving rural development. Brazil started the Luz Para Todos (Light for all - LPT) program in 2003 aiming at universalization of electricity access in the country, having provided electricity to 2.9 million households since its introduction (MME, 2012). The program is expected to be completed by 2014.

Minas Gerais is situated in the Southeast region of Brazil. It is relatively a large state with extensive rural areas distributed in a diverse geography. There are remote communities and households that are challenging to reach by the grid and the use of mini-grids or individual systems emerge as the only viable solution in these cases. This thesis examines the use of such systems in LPT in Minas Gerais. The role of decentralized power generation by renewable energy systems in rural electrification is explained through this specific case.

A deductive research method was used in this thesis. Research questions and hypotheses were formed following an extensive literature review. They were supported by observation of LPT thanks to an exchange program in Brazil and interviews with different stakeholders. The interviewees were experts at state authorities, concessionaires and the academia to give a broad and objective idea. Semi-structured interview method was used for a more flexible approach.

The specific objectives of the thesis are:

- To illustrate the use of decentralized renewable technologies in rural electrification programs, based on the analysis of a specific case (Minas Gerais)
- To analyze processes that take place in connection to the implementation of decentralized renewable energy technologies, within the context of LPT
- To analyze the limitations associated to these systems
- To discuss the keypoints for the promotion of further use of such technologies
- To define the factors that make decentralized renewables an alternative to grid extension

With the main research question as “What role do the decentralized renewable energy technologies play in rural electrification?”, the thesis is mainly focused on the following questions:

1. What is the reason behind using decentralized renewable technologies for rural electrification?
2. When do they emerge as an alternative to grid extension?
3. What is the role of such technologies in LPT?
4. What is the role of the legal framework when choosing the method of attendance?
5. How is the process of choosing the right technology for rural electrification?

LPT considers three technologies to electrify rural settings: (i) extending the national grid, or decentralized generation systems with (ii) isolated grids, and (iii) individual systems. Usually, the favoured option is the extension of the grid wherever it is technically and economically feasible, but in cases of municipalities that are located far from the grid, at a place where it is not feasible to extend the grid due to natural conditions (such as islands) or where the demand is too small, decentralized power generation could be more beneficial technically, environmentally and economically.

There are 5 concessionaires in the state, CEMIG, Energisa Minas Gerais, CPFL Mococa, Grupo Rede Bragantina and DME Distribution. CEMIG was the only concessionaire in Minas Gerais that used decentralized power generation with renewable energy within the scope of LPT. The concessionaire used individual PV systems to meet the demand for this type of generation in its area of concession. Therefore,
it is aimed that the role of decentralized generation by renewable technologies in LPT would be explained through this de facto use of individual PV systems.

ANEEL has issued the resolution No. 083/2004 to define the criteria to be followed by concessionaires when making individual connections. Until this resolution, there was no legal framework that regulated the use of stand-alone, also known as individual, systems. This resolution introduced a system called SIGFI - Sistema Individual de Geração de Energia Elétrica com Fonte Intermittente, meaning Individual System for Generation of Electrical Energy with Intermittent Source. There are 5 SIGFIs: SIGFI13, SIGFI30, SIGFI45, SIGFI60 and SIGFI80, with the number at the end referring to the monthly guaranteed availability of energy in kilowatt-hours. Playing an important role in universalization of access to electricity, there were three major drawbacks associated with this resolution: i) limited capacity of the systems; ii) public acceptance; iii) lack of incentives.

The use of mini-grids with renewable technologies is a new approach in Brazil. Mini-grids stand out as a long-lasting solution for communities that will not have the chance to be connected to the grid in the near to medium future. Since the release of the Manual for Special Projects in Luz Para Todos, mini-grids are considered as special projects and are supported with large incentives, including subsidies up to 85%. This approach favoured mini-grids over individual systems. Considering the fact that individual systems are more beneficial for electrifying households that are located far from each other, it is clear that these two methods of attendance serve for different purposes and should be both incentivised for larger use.

Decentralized systems were previously used in rural electrification in Brazil. Traditionally, PV was the most used renewable technology in decentralized generation in the country, with estimated number of 40,000 PV systems built (IEI, 2009). Having determined a market potential of 7,000 systems, CEMIG used 2,500 individual PV systems in LPT to meet its universalization goals (Diniz et al., 2011a). 2,500 systems represent 0.88% of the total connections by CEMIG in the program. There are various factors behind this low number and they are as follows:

- There were no incentives for the use of individual systems, which favoured grid extension in certain cases. (Incentives for mini-grids were introduced as late as 2009, but did not apply to individual systems)
- There was no stimulus for the national production of the systems, which could have lowered the costs.
- SIGFIs have low capacities. SIGFI13 and SIGFI30, systems commonly used for the electrification of households, are not capable of meeting the needs of beneficiaries.
- SIGFI does not imply a strict continuity of energy flow, which causes dissatisfaction amongst users
- There was a strong negative public view about SIGFIs, mainly related to their capacities. People believed that they would never receive grid connection in the future if they accept SIGFIs.
- Expansion of the grid decreased the number of cases where decentralized systems were financially advantageous.

Following the identification of the obstacles above, it is realized that regulatory framework and energy policy mechanisms largely shape the extent and features of rural electrification programs. The introduction of SIGFI was a major step for the regulation of individual systems, but it failed to satisfy neither concessionaires nor beneficiaries. Two drawbacks of the SIGFI that concerned beneficiaries were low capacities and long duration of non-operation. Lack of subsidies and high costs associated with systems were two factors that disfavoured the use of SIGFIs from the point of view of concessionaires. Therefore, it is clear that more efforts are needed to improve the regulatory framework to satisfy all stakeholders. These improvements will not only change the public view about the systems, but also lead to wider use in the future.

VIII
The example of LPT in Minas Gerais showed that decentralized power generation with renewable energy technologies was considered as an option when it was not economically and/or technologically feasible to extend the grid. Consumption potential, regional development, topography of the area to be electrified and the distribution of households to be connected were of high importance when determining the method of attendance. If necessary amendments are made in the regulatory framework, decentralized energy systems, either as mini-grids or individual systems, can play a larger role in rural electrification.

LPT succeeded in providing millions of people in Brazil with electricity, including almost 300,000 households only in Minas Gerais. The program is a great example to point out the importance of rural electrification in human development. Though realized to a limited extent, decentralized generation with renewable played an important role in the program and provided hundreds of households with electricity. Along with other programs created by the Brazilian government, LPT will be a milestone in Brazilian history for fighting inequalities and creating a socially unified and more developed country.
1 Introduction

1.1 Background

Rural electrification is a crucial step towards human development at a global level. According to IEA (2010), there were 1.441 billion people in the world, who did not have access to electricity in 2009. The rural electrification rate was reported to be only 65.1% in the same year. Not having access to electricity shows its effects on every aspect of rural life, leading to inadequate health and educational services, as well as lower income.

Brazil is a country of colours; the dazzling images of festivals and the “joie de vivre” represent its vibrant colours, while social inequalities and non-electrified citizens are colorless. As an important emerging market, Brazil seeks ways to fight against inequalities and work in unison to take a step further towards development. One essential step towards continued development is to cover the basic needs of citizens and the access to electricity is considered vital to move in this direction. According to ANEEL (2011), hydropower provides 71.21% of the electricity production in Brazil, followed by thermal generation with 26.2%, nuclear with 1.99% and wind with 0.82%. Small hydropower generation responds for 3.03% of the total electricity production (ANEEL, 2011). Photovoltaic and solar thermal generation are still quite small. The energy matrix of Brazil mainly consists of large hydropower plants. These plants are considered to be clean when it comes to electricity production, but their environmental impacts are widely criticized (Rosenberg et al., 1995). Other renewable energy technologies, such as small hydropower, photovoltaic applications and smallscale wind energy are emerging new renewable technologies that could play a major role in rural electrification.

The Brazilian rural electrification case is important, because it is instrumental for the achievement of the Millenium Development Goals in the country. Brazil is very challenging with its topography, distribution of municipalities and social structure. By the end of 2009, the electrification rate in the country was 98.3%, with 3.3 millions of citizens still waiting for the connection of electricity to meet their basic needs (IEA, 2010). Electrical exclusion is predominantly observed in rural areas of the country, where Human Development Indexes (HDI) are low. 90% of the families living in unelectrified areas in Brazil have an income of lower than one third of the minimum wage in the country (Andrade et al., 2011).

The Brazilian electricity industry experienced major changes since the 1990’s, starting with the privatization of utilities and the foundation of the Brazilian Electricity Regulatory Agency- ANEEL. Certain attempts to electrify rural areas were made following the changes in the sector. First, the Luz no Campo (Light in the Countryside) program offered electricity to consumers by grid extension, while the Programa de Desenvolvimento Energético de Estados e Municipios–PRODEEM (Program for Energy Development of States and Municipalities) mainly focused on rural community centres in remote locations, providing them with electricity from photovoltaic cells (Zerriffi, 2008). PRODEEM ended far from meeting its goals and the need to reach universalization of electricity access remained. This led to the creation of the Luz Para Todos (Light for all - LPT) Program in 2003, which set the ambitious goal of reaching universalization in electricity access until 2008 (Ruiz et al., 2007). Due to difficulties in reaching this goal, the program was extended until 2014, and the process is ongoing.

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1Millennium Development Goals are eight development goals established by the United Nations. They are expected to be achieved by 2015. Goals are planned to reduce poverty, diseases and child mortality amongst other improvements.

2 Human Development Index (HDI) is a composite index that combines life expectancy, education and income indicators. It was developed by the United Nations Development Programme.
This thesis is focused on the use of decentralized renewable energy technologies in LPT in the state of Minas Gerais. Minas Gerais is situated in the Southeast region of Brazil. Slightly larger than Metropolitan France, the population of the state is about 19 million inhabitants (IBGE, 2011). Larger than the two other well developed neighbouring states Rio de Janeiro and Sao Paulo, Minas Gerais contains large rural areas and various energy resources distributed in the state. It is a relatively rich state, but shows large differences of HDI within its localities, as shown in Figure 1. Most unelectrified areas in the state of Minas Gerais are in the Northern and Northeastern parts, as shown in Figure 2. The legends of the maps indicate colours and their equivalent intervals of HDIs (Figure 1) and electrification rates (Figure 2), with red representing the lowest interval and blue the highest interval. The histograms indicate frequency, with the height of the bar representing the level of frequency. The horizontal axes in histograms represent HDI in Figure 1 and electrification rate in Figure 2, increasing towards right. The maps shown in Figure 1 and Figure 2 match to a great extent and highlight the role of electricity in development.

![Figure 1: Map of distribution of HDIs in Minas Gerais](source: UNDP, 2000)
Figure 2: Residential electrification rates in Minas Gerais

Source: (UNDP, 2000)

The state of Minas Gerais houses a large installed potential of hydropower and shows good potential of solar power. There is also good wind potential, but it is usually concentrated in certain regions of the state. Considering that the state ranked fifth with the number of rural households without access to electricity and electrification rates varied dramatically between regions, the rural electrification case in Minas Gerais stands out as an interesting research subject. The particular reason for choosing Minas Gerais for this study is that the interconnected grid is well distributed in the state, which provides the opportunity to examine the conditions in which decentralized renewable energy technologies emerge as an alternative to grid extension. Figure 3 shows the number of rural households without access to electricity by states before the start of LPT.

Figure 3: Number of rural households without access to electricity by state

Source: (Filho, 2007)
Minas Gerais benefits from the national interconnected grid system. This means that the state is linked to the national electricity network, in which any generated electricity is fed to the grid to be used elsewhere, including the state where it is generated. This circumstance has promoted the extension of the grid to provide electricity in most rural areas. Though the most common technological option, grid extension is not the only solution offered by LPT in the state of Minas Gerais. Decentralized generation provides electricity to communities and households that are located in remote areas of the state. Renewable energy technologies, such as small hydropower, photovoltaics, wind power and biomass are ideal for small-scale power generation to supply communities and users in areas where it is not viable to extend the grid. Given the fact that large hydropower plants are no longer considered favourable due to environmental and socio-economic concerns, the use of abovementioned technologies emerge as a feasible way to reach universalization with less impacts on the environment.

1.2 Objectives

This master thesis analyzes the role that decentralized renewable technologies have played in the development of LPT in Minas Gerais. It provides an analysis of rural electrification in Minas Gerais, introduces LPT and examines the use of decentralized renewables in the program. This study aims to explain the need for using such method of attendance in rural electrification. It points out the advantages and disadvantages of such systems, as well as obstacles that limit their further deployment. Implementations of LPT by two concessionaires of different sizes in the same state, CEMIG and Energisa Minas Gerais, were compared to emphasize the cases where decentralized renewable technologies are considered as an alternative to grid extension. The specific objectives of the thesis are:

- To illustrate the use of decentralized renewable technologies in rural electrification programs, based on the analysis of a specific case (Minas Gerais)
- To analyze processes that take place in connection to the implementation of decentralized renewable energy technologies, within the context of LPT
- To analyze the limitations associated to these systems
- To discuss the keypoints for the promotion of further use of such technologies
- To define the factors that make decentralized renewables an alternative to grid extension

Regarding the deployment of decentralized generation by renewable energy technologies, this study only discussed the case of CEMIG. The company was the only concessionaire in Minas Gerais that used such method of attendance within the scope of LPT. Also, photovoltaic technology for individual generation was the only method of attendance to be discussed, because this was de facto the only decentralized renewable alternative used for remote areas. It is aimed that the role of decentralized generation by renewable technologies in LPT would be explained through this de facto sole use of individual PV systems. Therefore, the coverage of this study is limited to one technology implemented by a single company and readers are advised to keep in mind that decentralized renewables refer to individual PV systems in this specific study.

The information presented in this thesis reflects the ideas of different stakeholders, such as experts from the Ministry of Mines and Energy, ANEEL, LPT Program, the academia, CEMIG and Energisa Minas Gerais, except the beneficiaries. Also, it was not possible to reach specific information about the projects that were conducted within LPT, which could have been useful to see the length and costs of grid extensions and find out why decentralized renewable technologies were not preferred instead. Thusly, this approach was also excluded from this study.

With the main research question as “What role do the decentralized renewable energy technologies play in rural electrification?”, the thesis is mainly focused on the following questions:

1. What is the reason behind using decentralized renewable technologies for rural electrification?
2. When do they emerge as an alternative to grid extension?
3. What is the role of such technologies in LPT?
4. What is the role of the legal framework when choosing the method of attendance?
5. How is the process of choosing the right technology for rural electrification?

Following the literature review, certain hypotheses were formulated to analyze the role decentralized new renewable technologies in the specific case of Minas Gerais. Ruiz et al. (2007) have discussed the role of new renewable energies in governmental programs in Brazil, including rural electrification initiatives. Zerriffi (2007) reviewed distributed electrification in Brazil, presenting an in-depth analysis of the use of such technology in the country. Goldenberg et al. (2004) have provided information about weaknesses of rural electrification initiatives prior to LPT. Diniz et al. (1998; 2000; 2006; 2011) analysed the use of solar technologies in rural electrification in Minas Gerais and presented valuable information about the conditions and previous electrification experiences with solar energy in the state. Along with the mentioned resources, other studies also contributed to the formulation of the hypotheses in this study.

Formulated hypotheses are:

- Decentralized renewable energy technologies are used when it is economically or technologically unfeasible to extend the grid.
- Consumption potential, regulations, regional development, geographical features and the distribution of households determine the method of attendance in rural electrification.

1.3 Methodology

The Cambridge University Dictionary defines research as “A detailed study of a subject, especially in order to discover (new) information or reach a (new) understanding” (CUP, 2011). A problem usually leads to the need to conduct research. A deductive research method was employed in this thesis. Svensson (2009) explains and illustrates the deductive research process in his article as follows:

“Traditionally, the research process starts with an idea that is developed and made explicit through the research objective. One or several research questions are formulated that are supposed to contribute to the fulfilment of the research objective. Support of the idea is gathered as part of the research process. Initially, it is based upon research literature. It is followed by the empirical data collection. Implications are articulated that are theoretical and/or managerial. Finally, the contribution of the research process is outlined. Conclusions are drawn and suggestions for further research are usually provided. The research process re-connects to where it all started, thereby completing the circle.”

![Figure 4: Deductive research process](image)

Source: (Svensson, 2009)
According to this system, our problem in this thesis is the unknown role of decentralized renewables in LPT in Minas Gerais. As mentioned in the previous sections, this problem led to the creation of the research objectives and research questions, as well as the hypotheses, represented as “Idea” in Figure 4. These objectives were supported by an extensive literature survey, the observation of LPT thanks to an exchange program in Brazil and interviews with different stakeholders during this period. The interviews included responsibilities at state authorities, concessionaires and the academia to give a broad and objective idea about the subject. Semi-structured interview method was used in this study for a more flexible approach. Semi-structured interviews allow interviewees to express their personal ideas, while providing the interviewer with the ability to develop an interview guide beforehand (RWJF, 2008). The exchange period in Brazil was also instrumental in collection of materials that were not included in the literature review, so they greatly contributed to the research objectives. A complete list of the interviewees is provided in Table 1.

Table 1: Information about the interviewees who contributed to this study

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Date</th>
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Upon completion of supporting documents and interviews, the previously created questions and hypotheses were answered by implications. At this point, the previously created hypotheses were evaluated to be valid or not valid. The same implications led to conclusions and contributed to clarify the situation of decentralized renewable energy technologies in LPT in Minas Gerais. Following the conclusions, suggestions to support further expansion of such technologies were made and the directions for future research were mentioned, reaching the starting point of the research process.
1.4 Structure of the Thesis

This thesis contains six chapters:

Chapter 1 introduces the subject and provides some definitions. Then, objectives, scope and limitations related to this study are discussed. This is followed by formed research questions and hypotheses. This chapter concludes with the presentation of the methodology used in the study.

Chapter 2 presents rural electrification in Brazil and Minas Gerais. It provides information about previous rural electrification programs, then introduces the present rural electrification program, Luz Para Todos. Brief information about the past of rural electrification in Brazil is presented to point out the differences brought by LPT. This is followed by giving information about LPT, defining actors, explaining the guidelines and processes that have to be followed and giving information about the financial framework of the program.

Chapter 3 discusses LPT in Minas Gerais. First, brief information about Minas Gerais and its regions is presented. Following this, information about the concessionaires in the state is provided. The two largest concessionaires in the state, CEMIG and Energisa MG were selected to study the implementation of the program. A comparison between the two concessionaires is presented to define the role of concessionaires in the program and point out circumstances that shape their decisions in LPT, relating this to the deployment of decentralized renewable energy technologies.

Chapter 4 discusses the decentralized renewable energy technologies used in LPT in Minas Gerais. The chapter starts by defining the role of renewable energy technologies in rural electrification. This is followed by a description of the legal framework for using such technologies. Then, the role of the new renewable energy technologies in LPT is analysed. The overall process followed for the implementation of such technologies at CEMIG is described. This chapter concludes by giving technical information about the PV systems used in Minas Gerais within LPT.

Chapter 5 analyzes the gathered information and presents implications. It concludes the study by answering the research questions and providing ideas to overcome limitations and promote further expansion.
2 Rural Electrification in Brazil

In this section, rural electrification in Brazil and Minas Gerais is presented. Previous rural electrification programs in Minas Gerais are briefly mentioned and LPT, the current rural electrification program in Brazil, is introduced. First, brief information about the Brazilian electricity sector is provided, then its key actors in rural electrification are defined. Rural electrification programs, either statewide or national, in Minas Gerais prior to LPT are compared and the role of decentralized renewable energies in these programs is discussed. It is followed by presentation of LPT, its operational and financial structure, as well as the steps followed for the implementation of projects in the program. One of the most important points in rural electrification, the prioritization of the projects in LPT is also discussed in this section.

2.1 Electricity Sector and Rural Electrification in Brazil

Brazil is the largest and most populous country in South America. The country spans on an extensive area of land, which shows great differences between regions. These differences do not only refer to geographical differences, but also financial and social differences. The country is divided into 5 regions: North; Northeast; Central-West; Southeast; South. Minas Gerais is located in the more developed Southeast region of Brazil. Brazilian states and regions are shown in Figure 5.

![Figure 5: States and regions of Brazil](Source: (FAO, 2004))

The electricity transmission and distribution network of Brazil is the largest in South America with 113,327 MW installed capacity by the end of 2010 (ANEEL, 2011). The electricity is mainly generated from hydropower with 71.21%, mostly consisting of large hydropower plants (ANEEL, 2011). There have been major changes in the electricity market in the 1990’s, including privatization of some state owned companies, introduction of regulatory institutions and creation of a competitive market (Wanderley et al., 2011). Before the reforms, the Brazilian electricity sector was a monopoly, like in many other countries.

Today, the Brazilian electricity sector has a hybrid nature with two different contracting methods. The Regulated Contracting Environment (Ambiente de contratação regulada - ACR) deals with long term agreements between generation and distribution utilities that serve captive consumers, while the Free
Contracting Environment (Ambiente de contratação livre - ACL) allows large consumers with consumption over 3MW to freely choose the providing companies, usually with short-term contracts (Wanderley et al., 2011). Carpio and Margueron (2010) argue that Brazil and other important developing countries worldwide have chosen a hybrid regulatory framework, because they are able to benefit medium or large size clients with a freedom of choice of energy supplier and, at the same time, protect the greater part of its small residential consumers that still need to be supported by social policies to supply their basic energy needs.

Brazil has regulations that protect low-income residential consumers, called the social tariff. The idea behind the regulations is to let low-income families have access to electricity with discounted prices. The law, which created the social tariff, was changed in 2010 to achieve a more equal nature by establishing new criteria to provide the benefit. Previously, this benefit was only dependent on the consumption. Today, besides a specific consumption level, the beneficiaries need to prove that they are registered in a social program. Only low-income citizens can register in these programs. The social tariff offers 65% discount for low-income residential consumers with monthly consumption up to 30kWh; 40% discount is applied for those who consume between 31-100kWh/month; and consumers with a monthly consumption between 101-220kWh receive 10% discount. The bills are calculated in cumulative system. Quilombolas3 and Indigenous communities have 100% discount if their monthly consumption do not exceed 50kWh (Ministry of Social Development and Fight Against Hunger, 2010). In this way, the universalization law and LPT are associated with social policies introduced by the Brazilian government.

Introduction of the universalization law created an obligatory new market for concessionaires to invest in and LPT has served to facilitate this process. According to the law, concessionaires are obliged to provide electricity to all people in their areas of concession. Considering the high number of connections and related costs due to distances, a program like LPT was necessary to support the concessionaires and speed up the process of electrification. The most important actors in this process are: Ministry of Mines and Energy, the national electricity company (ELETROBRÁS), the regulatory agency (ANEEL), states and concessionaires.

LPT provided electricity to 2.9 million households, introducing 14.5 million people with electricity since its introduction (MME, 2012). Especially North and Northeast regions of the country were significant for their low HDIs and challenging conditions. Therefore, 49% of the connections were realized in the Northeast Region of the country. It was announced in January 2012 that 414,000 connections were left before the completion of the program, of which a large number are in the North, especially in the Amazon Region (MME, 2012). Unlike Minas Gerais, there is no connection to the national grid in the Amazon Region, so the only methods of attendance are individual systems and mini-grids. Thereby, the case of Minas Gerais emerges as a good example to point out the factors that make decentralized power generation competitive against grid extension.

Though the current universalization program is LPT, there were various rural electrification programs in Brazil and in Minas Gerais before its creation. It is beneficial to have an idea about previous programs for a good understanding of LPT and its new approach to rural electrification.

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3 Quilombolas are descendents of slaves that escaped from slavery and settled in remote areas before the end of slavery in Brazil in 1888.
2.2 Rural Electrification Programs in Minas Gerais

Brazil has large rural areas that are spread all over the country. In the beginning of the 1990’s, rural areas started receiving attention from the authorities, because meeting the basic needs of citizens became a subject of discussion at international level. Along with other countries, Brazil aimed to provide access to electricity in its rural areas by creating several rural electrification programs. Some of these programs were federal programs, while others were specifically created for certain states or concessionaires.

For tens of years, grid extension was almost the only option to provide rural communities with electricity. These communities were often located close to the main grid. Remote communities, located far from the grid, used to be (and still are) provided by diesel generators in certain regions in Brazil. Towards the end of the 1990’s, photovoltaic technology emerged as a promising alternative for generating electricity in rural areas and created electrification opportunities for communities located in areas where it was not possible to extend the grid. Minas Gerais also have rural communities all over the state, though the concentration is higher in certain regions. The main concessionaire in Minas Gerais, CEMIG, was always supportive of social programs including rural electrification, allocating 5% of its profit for that purpose (Diniz et al., 2000). According to investigations of CEMIG, the areas where PV systems can perform best are in the Western and Northern parts of Minas Gerais, with global solar radiation averages over 5 kWh/m²/day (Diniz et al., 2000).

As observed in Figure 1 and Figure 2, the Northern part of Minas Gerais shows almost the lowest HDIs in the state, as well as low electrification rates. So, this region is very suitable for such rural electrification programs, not only because of its high solar radiation rate, but also because of the potential to promote rural development. Table 2 provides information about the past rural electrification programs, either nationwide or statewide, that were implemented in Minas Gerais between the early 1990’s and LPT.
Table 2: Previous rural electrification programs in Minas Gerais

<table>
<thead>
<tr>
<th>Name of the program</th>
<th>Extent</th>
<th>Year</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program of Assistance for Rural Development in Brazil</td>
<td>Brazil</td>
<td>1995-1996</td>
<td>A joint project between CEPEL, DOE and NREL, the program resulted with 71 installed PV systems, of which 17 were for schools, 42 for rural houses and 12 for community centres.</td>
<td>Led to the first fully electrified community by PV in Minas Gerais, Macacos in Comercinho municipality.</td>
</tr>
<tr>
<td>The GTZ Technical Cooperation</td>
<td>MG</td>
<td>1995-1996</td>
<td>Result of a technical cooperation between CEMIG and GTZ, the project led to installation of a PV water pumping irrigation system in the Northern part of MG and electrification of two communities in Diamantina.</td>
<td>The two electrified communities in Diamantina were Içara and Mão Torta.</td>
</tr>
<tr>
<td>COPASA</td>
<td>MG</td>
<td>1997-1999</td>
<td>COPASA created a program that would focus on water pumping by PV systems in the state. The initial aim of program was installation of 200 systems, of which 48 were completed in 1997.</td>
<td>There is no actual information about the status of the systems.</td>
</tr>
<tr>
<td>Luz de Minas</td>
<td>MG</td>
<td>1995-2000</td>
<td>Initiated by CEMIG in 1995, the program aimed to electrify 100,000 households by grid extension, PV systems and conventional technologies. 4,700 installed systems in the program were expected to consist of PV technology.</td>
<td>CEMIG covered 64% of the costs, while the municipalities paid the rest, 36%.</td>
</tr>
<tr>
<td>PRODEEM</td>
<td>Brazil</td>
<td>1994-2001</td>
<td>A nationwide rural electrification program with a focus on renewables. Schools and community centres were prioritized. Over 9000 PV systems were built, making a total installed power of 5 MWp. Within PRODEEM, CEMIG has started the PV Communal Center Program, which provided 13 schools in 12 rural municipalities in Jequitinhonha Valley with a total number of 37 PV systems.</td>
<td>The program failed to reach its goal. Most of the systems were either stolen or out of service shortly.</td>
</tr>
<tr>
<td>The Plan of Revitalization and Training of PRODEEM</td>
<td>Brazil</td>
<td>2001-2005</td>
<td>The program aimed to repair and adjust the operational systems that are left from PRODEEM.</td>
<td>It became a part of LPT in 2005 and left materials have been used in the new rural electrification program.</td>
</tr>
<tr>
<td>Luz no Campo</td>
<td>Brazil</td>
<td>2001-2004</td>
<td>With a goal of reaching 1 million beneficiaries by grid extension, the program suffered from lack of funds due to financial burdens on the concessionaires.</td>
<td>The program was merged with LPT in 2004.</td>
</tr>
<tr>
<td>Luz Solar</td>
<td>MG</td>
<td>1999-2003</td>
<td>Luz Solar Rural Home Pre-electrification with Photovoltaics Subprogram intended to install 500 individual PV systems for households in rural Minas Gerais.</td>
<td>The idea behind this program was to provide electricity to communities by PV systems until they grow to become feasible to be connected to the grid, then transfer the equipment to another community in need. CEMIG funded 87% of costs that were related to the program, with the remainder being covered by municipalities where the electrified areas are located.</td>
</tr>
</tbody>
</table>
<pre><code>                                                                                                             | Luz Solar Rural School and Community Electrification Subprogram aimed to electrify and provide potable water to 800 schools in 300 communities that were located in areas with the lowest HDIs |                                                                                                                                                                                                                                                         |
                                                                                                             | Photovoltaics Solar Energy Training Subprogram mainly focused on the sustainability of the program. This was planned to be achieved by training users and maintenance technicians. |                                                                                                                                                                                                                                                         |
</code></pre>

Source: (Borges Neto et al., 2010); (Diniz et al., 1998; 2000; 2006); (Goldemberg et al., 2004); (Zerriffi, 2008)
The information presented in Table 2 shows the efforts by the Brazilian government, the state of Minas Gerais and CEMIG for rural electrification in Minas Gerais, starting from the mid 1990's. Even though programs like Luz no Campo and Luz de Minas mainly used grid extension, PV systems were always the sole alternative for areas that were difficult to reach in Minas Gerais. Taking into account that PV technology was in an experimental phase, CEMIG's approach was innovative at the time (Diniz et al., 1998). The company's attitude did not only support the use of this technology, but also led to development in Minas Gerais, making the state one of the pioneers in PV technology and rural development. CEMIG's ambitious stance for such systems is also a good example to point out the importance of concessionaires for development of certain technologies locally. Previous rural electrification programs with PV systems provided CEMIG with experience and facilitated further use of this technology in LPT.

2.3 Luz Para Todos

The actual rural electrification initiative is in the hands of Luz Para Todos (Light for all) Program. It was created by the Decree No. 4.873 of November 11th 2003 and was later extended by the Decrees No. 6.442 of April 25th 2008 and No. 7.520 of July 8th 2011. The program initially aimed to reach universalization of the access to electricity throughout the country by 2008. Then, due to problems encountered and growing demand, the deadline was first extended to December 2010 and now is set for 2014.

The program is mainly directed to rural areas, where, according to IBGE (2012), the electrification rate is 92.6%. There were 2 million rural households in Brazil, which did not have access to this basic service (MME, 2011a). Low electrification rates usually go hand in hand with low HDIs. Absence of electricity leads to low economic productivity, insufficient education, poor healthcare and low quality of life. Connection of low-income households in rural areas is not considered profitable by electricity companies due to the high investments and low return rates. As it is not realistic to expect low-income consumers to pay the expenses to be connected with electricity, the program encourages any citizen to apply and receive electricity with no connection costs. LPT offers subsidies and loans to Executing Agents to make sure that there are no financial obstacles in this process. Executing Agents could be concessioners, electricity distribution permittees and rural electrification cooperatives that are authorized by ANEEL.

LPT does not only provide connection to electricity, but also requires installation of the necessary infrastructure at households and communal centres. According to the defined criteria in the LPT manual, Executing Agents install at least 1 illumination point in every room up to maximum 3 rooms, 2 plugs and other necessary equipments, such as 9W or 11W fluorescent lamps (MME, 2011a). They also provide information to beneficiaries about how to use the system.

According to a study about the impacts of LPT, households who had limited income have benefited from better production and job opportunities, which supported them financially (MME, 2009). The arrival of electricity was also powerful to reduce the use of conventional energy resources, which not only cause greenhouse gas emissions, but also threaten the health and safety of households. Electricity creates job opportunities, higher production, better healthcare, improved educational activities and adult education at night, as well as improvement in personal hygiene. Looking at the larger picture, LPT did not only offer a better life to its beneficiaries, but also caused economic mobility and improvement of national production by creating a demand for electronic appliances. 2 million beneficiaries of the program created a demand for 1,586,000 TV sets, 1,466,000 refrigerators and 780,000 mixers (MME, 2009). Another important point that was noticed during the study was the inequal social structure of Brazil. Especially the North and Northeast are underdeveloped compared to other parts of the state and show the lowest HDIs and electrification rates. The inequalities are also observed in the cities, where there are areas without adequate infrastructure. Upon the widespread electrification by LPT, many people returned to rural areas from shantytowns in large cities, causing a vegetative growth in the demand to be connected to electricity (FURNAS, 2011).
Briefly, electricity is the driving force of modern life and there is a big difference between its absence and presence. Thereby, LPT is not only about providing electricity to people, it is also about fighting inequalities and taking steps towards human development. That is why the program has not only a technical mission, but also a very large social mission.

2.3.1 Operational Structure

The operational structure of LPT consists of commissions and committees, as well as various agents, which are illustrated in Figure 6. These are:

National Universalization Commission (Comissão Nacional de Universalização – CNU): National Universalization Commission has various ministers, the president of National Bank of Economic and Social Development, the president of National Forum of State Secretaries for Energy, as well as the general director of Brazilian Electricity Regulatory Agency-ANEEL. The aim of this commission is to create policies and guidelines to use electricity as a driving force to reach rural development.

Ministry of Mines and Energy (MME): The Ministry of Mines and Energy coordinates the program and forms policies. It is one of the stakeholders to sign the agreement and it also forms and guides the State Management Committee (Comitê Gestor Estadual – CGE), as well as regional coordinators.

The Ministry of Mines and Energy reviews the work programs that it receives from ELETROBRÁS and gives feedback, so ELETROBRÁS can sign contracts with Executing Agents. It also informs the states about their financial responsibilities for the accepted work programs. The technical and financial monitoring of the program is also undertaken by the Ministry.

National Management Committee (Comitê Gestor Nacional – CGN): National Management Committee is coordinated by the Ministry of Mines and Energy and its participants are representatives from ELETROBRÁS, ANEEL, Brazilian Electricity Distributors Association (ABRADEE), Brazilian Cooperatives Organization, as well as presidents of Regional Coordinators. The National Management Committee evaluates incoming information from the State Management Committees, analyses the problems encountered and observes the progression of the program.

Regional Coordinators: Regional coordinators are representatives from ELETRONORTE, CHESF, FURNAS and ELETROSUL, standing for different regions in the country. ELETRONORTE deals with the North region, CHESF Northeast, FURNAS Southeast and Centerwest, ELETROSUL South. Minas Gerais is in FURNAS. Regional coordinators make sure that everything works according to the regulations defined by the Ministry of Mines and Energy and inform the ministry about the status of ongoing projects in their respective regions.

State Management Committee (Comitê Gestor Estadual – CGE): The State Management Committee mainly consists of representatives from the state, Ministry of Mines and Energy and Executing Agents. If needed, representatives from various institutions could also be invited. The Committee evaluates the demand according to the prioritization criteria of the program, helps the Executing Agents to meet their attendance goals, monitors the physical and financial situation of the projects undertaken in the state and reports information about the projects to the regional coordinator. The Committee is also responsible for identifying possible ways to use electricity to reach rural development in the state, as well as monitoring such actions.

Brazilian Electric Power (ELETROBRÁS): ELETROBRÁS signs the initial agreement with other stakeholders. It analyses work programs financially and technically and reports to the Ministry of Mines and Energy. If there is a need of alteration in the work program, ELETROBRÁS is responsible for these alterations to be suitable to predefined regulations. Upon authorization of the work program by the Ministry of Mines and Energy, it signs contracts with Executing Agents regarding the financial resources to be given. ELETROBRÁS inspects the projects and makes the financial resources available for Executing Agents accordingly. It is also responsible for monitoring the use of financial resources by the
Executing Agents and reports the statuses of projects and the release of financial resources to MME, Regional Coordinators and State Management Committees.

**Executing Agents (Concessionaires, Electricity Distribution Permittees and Rural Electrification Cooperatives):** Executing agents sign the initial contract between all stakeholders. They assess the electrification demand in their areas and create work programs, then hand these to ELETROBRÁS. They sign contracts with ELETROBRÁS and the states about the reception of financial resources. Executing Agents implement the work programs according to prioritization criteria of the program and inform the Ministry of Mines and Energy and ELETROBRÁS regarding the physical and financial statuses of the projects. They are obliged to inform the beneficiaries about the efficient use of electricity and safety precautions. The Executing Agents are also responsible of the reception of electricity by the end users, including installations in the households with plugs and supply of energy saving lamps.

**Agents of Luz Para Todos:** Agents of the program are responsible for informing and encouraging communities and municipalities about the program. They monitor the statuses of the projects undertaken and visit the areas for the assessment of possible social outcomes from the program. They act as a messenger to hand the demand from municipalities to State Management Committees.

**The States:** The states sign the initial agreement, where the attendance goals and resources are defined. They also make contracts with Executing Agents regarding the flow of financial resources.

**Brazilian Electricity Regulatory Agency (Agência Nacional de Energia Elétrica–ANEEL):** A participant of National Committee of Universalization, National Management Committee and State Management Committee, ANEEL signs the initial agreement that includes all stakeholders.

![Figure 6: Different stakeholders at LPT](image)
2.3.2 Criteria for the Prioritization of Projects

LPT prioritizes projects to be implemented. The reason behind this is to help people in worse living conditions first and to have outcomes of the program faster, where there are possibilities of using electricity for development. The higher number of criteria met by a project, the higher chances that it will be implemented. These criteria are described below:

- Municipalities with HDIs below 0.800
- Municipalities with HDIs below the state average
- Communities that are affected by hydropower projects or work related to electricity system
- Rural electrification projects which will lead to increased production and development
- Rural electrification projects where public schools, health institutions and supply of well water to the community are included.
- Projects in rural settlements
- Rural electrification projects that will support agriculture or craftsmanship as family business.
- Projects that will support small or medium farmers
- Rural electrification projects that could not be completed due to financial problems
- Rural electrification projects that are dedicated to communities living close to National Parks.
- Rural electrification projects that are dedicated to communities consisting of minorities, such as Quilombolas, Indigenous etc.

2.3.3 Methods of Attendance

LPT considers three technologies to electrify rural settings: (i) extending the national grid, or decentralized generation systems with (ii) isolated grids, and (iii) individual systems. Usually, the favoured option is the extension of the grid wherever it is technically and economically feasible. Taking the fact into account that the Brazilian Energy Matrix is dominated by hydropower, extending the grid does not raise questions in terms of carbon emissions, but in cases of municipalities that are located far from the grid, at a place where it is not feasible to extend the grid due to natural conditions (such as islands) or where the demand is too small, decentralized power generation could be more beneficial technically, environmentally and economically.

LPT requires the Executing Agents to assess all possible technologies, materials, equipments and services and implement the most economic option. These assessments are done depending on the community to be electrified, as special conditions might require more expensive techniques to be employed. The costs that are mentioned by the Executing Agents regarding the projects must be compatible with reference costs of ELETROBRÁS.

The LPT manual lists the following technologies suitable for decentralized generation systems with isolated grids (mini-grids):

- Micro and mini hydropower, including hydrocinetic
- Small hydropower
- Small Diesel thermal power
- Small solid biomass thermal power
- Photovoltaics
- Wind power
- Power generating small internal combustion motor systems with vegetable oil in natura (produced in the region), biodiesel (produced in the region) or biogas (methane from a digester) as fuel.
- Hybrid systems, consisting two or more of the technologies mentioned
In case of the use of individual systems, following technologies could be employed:

- Hydroelectricity
- Photovoltaics
- Wind energy
- Biomass
- Hybrid systems, consisting two or more of the technologies mentioned

2.3.4 Implementation of Projects

As defined in the manuals of the program, official steps should be followed by actors to provide electricity to beneficiaries. The process is illustrated in Figure 7. It starts with an agreement to be signed between the Executing Agents and Ministry of Mines and Energy, ANEEL and ELETROBRÁS. The contract considers a work program by filling out standardized forms, where the number of beneficiaries, the materials and services to be used, with their costs are expressed in detail. The next step would be the financial and technical analysis of the work program by ELETROBRÁS with assistance of the Ministry of Mines and Energy. If the work program meets the foreseen criteria, it will be handed to the Ministry of Mines and Energy for review. If the result of the review by the Ministry is positive, the work can be executed. For the financial aspect of the projects, there should be two separate agreements to be made by the Executing Agents. One of them is to be signed between the Executing Agent and ELETROBRÁS regarding the release of financial resources from the Energy Development Account (CDE)\(^4\) and Global Reverse Fund (RGR)\(^5\) and the other one is to be signed by the Agent and its respective state for the release of financial resources and their forms. The states are informed by the Ministry of Mines and Energy regarding the amount of resources that they will have to allocate for the project and they are responsible for a smooth flow of these financial resources to ensure the continuity of the program.

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\(^4\) CDE is a form of subsidy, for further details see page 18
\(^5\) RGR is a form of soft loan, for further details see page 18
2.3.5 Case of Special Projects

There are some additional procedures to be followed in cases of the grid being extended in extreme conditions (underwater, through forest etc.) and decentralized generation systems with isolated grids. These projects are regarded as “special projects” and they provide guidelines for the implementation of mini-grids in areas that are far from the grid. The Executing Agents prepare pre-projects to be handed to ELETROBRÁS. Upon acceptance of this pre-project, they prepare the main project and continue with the process accordingly.

Projects that employ mini-grids should prove that the choice suits best the local or regional energy potential, in terms of economic feasibility and resource availability. For example, pre-reports should include the potential for development of the technology in the respective area. If biomass-driven technologies are to be used, the pre-report should include the local potential for sustainable production of biofuels and a study that shows a specific consumption below 0.3 l/kWh if the system uses fossil fuels (MME, 2011a).

The eligibility criteria for providing the service are compatible with the prioritization criteria that are defined for regular projects; prioritization of isolated communities, especially the Amazon region; use of the best local energy resource potential; prioritization of decentralized systems with isolated grids; supply of the energy demand for households to meet basic needs upon a pre-study to define the demand; a technical and financial viability analysis for communal centres; compliances with previously defined
It is obligatory for the implemented systems to meet basic needs of the households, such as lighting and communication. Executing Agents are asked to consider technologies that are most suitable to the region of the project, either financially or regarding energy resources availability. All safety measurements should be taken to prevent any accidents caused by the systems. Executing Agents are also responsible for the internal installation of the electrical structure, as well as plugs and supply of energy saving fluorescent lamps. For the sustainability of the system, Executing Agents are also asked to take environmental constraints and education of users into account.

2.3.6 Financial Structure

The financial structure of the program is explained widely in the manual of the program and consists of four resources: (i) Energy Development Account (CDE); (ii) Global Reverse Fund (RGR); (iii) States and Municipalities; and (iv) Executing Agents. The Federal Government, the states and Executing Agents sign a contract that defines the annual goals and financial resources that would contribute to the program, with the intervention of ANEEL and ELETROBRÁS.

The Energy Development Account (CDE) is a form of subsidy to promote the use of alternative energies, as well as universalization of electricity access. The Executing Agent is obliged to pay 1% of this subsidy as tax for administrative costs (MME, 2011a). This fund is maintained by annual payments from concessionaires for using public property and penalties by ANEEL.

The Global Reverse Fund (RGR) provides funds in the form of a credit (though it could be used as a subsidy in special cases with permittance of Law No. 10.762 of November 11th 2003) that could be used for alternative energies, increasing energy efficiency or universalization of electricity access. This fund is replenished by monthly payments by the concessionaires of generation, transmission and distribution of electricity. This credit has 5% annual interest rate with monthly payments to be paid back (MME, 2011a). States and Municipalities can also provide funding for the program as subsidies. These subsidies are transferred to the Executing Agent with respect to legal agreements made between the Executing Agent and the state. Finally, the Executing Agents will have to finance the rest, especially expenses that are not guaranteed under the agreement.

What makes LPT distinctive from previous rural electrification programs is that it is largely based on financial support from the Brazilian state to accomplish the goal to reach universalization in the country, even including the areas where it is least feasible for a company to invest in. The liberation of the available resources within the program occurs step by step, depending on the progress of the respective project that the resources are allocated for. The liberation of the resources is dependent on the contracts that are signed between ELETROBRÁS and Executing Agents. All necessary contracts should be signed for the reception of the down payment by the Executing Agents. Projects in LPT are categorized in two ways as mentioned previously, one of them is regular projects that involves normal grid extensions and individual systems, the other one is called “special projects” that deals with isolated grids and grid extensions with special conditions (such as extension under bodies of water or through a jungle). There are different financial conditions for regular projects and special projects.
Financing of Regular Projects

Financing of regular project involves several steps. There are some conditions that should be met in order to receive such payments. They are explained fully in the manual for the program, but it could be useful to mention them shortly. Following conditions should be met:

- Completion of all necessary contracts for the transfer of resources
- Compliance with sectoral agreements referred at the article 6 of the Law No. 8.631/93 about the use of CRC funds.
- Executing Agent should not have a record of previously unpaid loans.
- Due performance certificate, issued by ANEEL
- Availability of RGR and CDE resources
- Ownership of a currency account in the name of the Executing Agent for tracking of payments.
- Issue of promissory notes regarding RGR resources by Executing Agent.

The transfer of the resources happens according to the principles mentioned in Table 3.

Table 3: Payment process for regular projects in LPT

<table>
<thead>
<tr>
<th>Installment</th>
<th>Conditions</th>
<th>Liberation of the Resources (% of the value in the contract)</th>
<th>Received Resources (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Down payment</td>
<td>Upon completion of necessary contracts</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Second payment</td>
<td>Upon approval of 10% progress by ELETROBRÁS and financial verification</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>Third payment</td>
<td>Upon approval of 30% progress by ELETROBRÁS and financial verification</td>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>Fourth payment</td>
<td>Upon approval of 50% progress by ELETROBRÁS and financial verification</td>
<td>Up to 20</td>
<td>Up to 90</td>
</tr>
<tr>
<td>Final payment</td>
<td>Upon final inspection by ELETROBRÁS and final financial verification. In case that the conditions are not met, the resources shall be paid back to ELETROBRÁS.</td>
<td>Up to 10</td>
<td>Up to 100</td>
</tr>
</tbody>
</table>

Source: (MME, 2011a)

There could be intermediate payments, given that the amount is equal or more than 10% of the value of the contract and the progress and financial aspects are confirmed by ELETROBRÁS.
**Financing of Special Projects**

Special projects also have a different resource flow from regular projects. They are supported 85% by Energy Development Account (CDE) as subsidies, and 15% by the Executing Agents. The subsidies aim to cover direct costs that are related to the projects.

The conditions to be met for the transfer of the resources to Executing Agents are the same as regular projects, but the payment process occurs differently. Table 4 shows the payment structure of special projects:

<table>
<thead>
<tr>
<th>Installment</th>
<th>Conditions</th>
<th>Liberation of the Resources (% of the value in the contract)</th>
<th>Received Resources (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Down payment</td>
<td>Upon completion of necessary contracts</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Second payment</td>
<td>Upon reception of the materials and equipments that are presented financially in the contract and approved by the State Management Committee</td>
<td>Up to 60</td>
<td>90</td>
</tr>
<tr>
<td>Final payment</td>
<td>Upon final inspection by the engineers of ELETROBRÁS and final financial verification, which is done upon reception of the final comissioning report from the Executing Agent</td>
<td>Up to 10</td>
<td>Up to 100</td>
</tr>
</tbody>
</table>

Source: (MME, 2011a)

This chapter presented an overview of rural electrification programs in Brazil and Minas Gerais. It also provided a description of LPT, its operational and financial structure. Based on this, next chapter elaborates on the specific case of Minas Gerais.
3  Luz Para Todos in Minas Gerais

In this section, LPT in Minas Gerais is presented. The state of Minas Gerais, its regions and the differences between these regions are described. This description is followed by presentation of the concessionaires in the state. A comparison in terms of area of concession, the number of customers and participation in LPT was made. Then, information about the two major concessionaires in the state, CEMIG and Energisa Minas Gerais, and their participation in the program are analyzed. At the end of the section, a critical comparison in terms of implementation of LPT was made between the two concessionaires.

3.1 Minas Gerais and the Concession System

The state of Minas Gerais is spread over 588,384 km² of land that takes up 6.9% of the Brazilian territory and 63.5% of the Southeast region (Scavazza, 2003). It is the second most populous state with 19,597,330 inhabitants and comes fourth in terms of the area that it occupies. The growth rate of population in Minas Gerais was reported to be 0.91% between the years 2000-2010. According to the 2010 census, the population density of the state is 33.41 inhabitants/km² (IBGE, 2011). The large nature of the state and the differences between regions led to creation of a very diverse society, which also shows significant inequalities.

There are ten administrative regions in the state of Minas Gerais. These regions are: Noroeste de Minas (Northeast of Minas); Norte de Minas (North of Minas); Centro-Oeste de Minas (Centre-West of Minas); Jequitinhonha/Mucuri; Rio Doce; Triângulo; Alto Paranaíba; Sul de Minas (South of Minas); Zona da Mata; Central. Figure 8 shows the regions in the state.

Figure 8: Administrative regions of Minas Gerais
Source: (Minas Gerais State Integrated Development Institute, 2011)
Minas Gerais is home to different geographical characteristics and cultures, which had large impacts on the implementation of LPT. The Central and Southern parts of the state are developed with larger cities and good infrastructure, while the North shows characteristics of a typical rural region with low income and financial activity. The North also houses Quilombolas and Indigenous communities, who live in more isolated areas. Alto Paranaiba region is the less densely populated region in the state, while the Central region is the most densely populated and urbanized. Jequitinhonha/Mucuri region, known for its lower quality of life and income, is the region that has the lowest urbanization rate. The North region, which has the second lowest population density, is part of the SUDENE program along with Jequitinhonha/Mucuri region.

It is possible to say that the interconnected grid is well distributed in the state, though there are difficulties associated with certain regions of the state. Previous problems encountered in rural electrification in different regions until 2003 were incorporated by CEMIG in universalization plans that were handed to ANEEL after the introduction of the universalization law. Most experienced problems were large extensions of the grid due to distances, low population density and low purchasing power. Table 5 presents information about the difficulties experienced in previous rural electrification programs in the regions of Minas Gerais.

<table>
<thead>
<tr>
<th>Region</th>
<th>Problems encountered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alto Paranaiba Region</td>
<td>Large extensions and low population density</td>
</tr>
<tr>
<td>Central Region</td>
<td>No difficulties reported</td>
</tr>
<tr>
<td>Centre-East Region</td>
<td>No difficulties reported</td>
</tr>
<tr>
<td>Jequitinhonha/Mucuri Region</td>
<td>Long distances, low population density and purchasing power</td>
</tr>
<tr>
<td>Mata Region</td>
<td>No difficulties reported</td>
</tr>
<tr>
<td>North Region:</td>
<td>Large extensions, low population density and purchasing power</td>
</tr>
<tr>
<td>Northeast Region</td>
<td>Large extensions and low population density</td>
</tr>
<tr>
<td>Rio Doce Region</td>
<td>No difficulties reported</td>
</tr>
<tr>
<td>South Region</td>
<td>No difficulties reported</td>
</tr>
<tr>
<td>Triângulo Region:</td>
<td>Proximity of certain consumers to environmentally protected areas.</td>
</tr>
</tbody>
</table>

Source: (ANEEL, 2004a)

The state of Minas Gerais consists of 853 municipalities. All municipalities are electrified, leaving 20,000-30,000 households before the completion of the program in Minas Gerais in 2012 (FURNAS, 2011). There are 5 concessionaires in the state, CEMIG, Energisa Minas Gerais, CPFL Mococa, Grupo Rede Bragantina and DME Distribution. 774 of the municipalities are within the concession area of CEMIG, while Energisa Minas Gerais is responsible for 65, Grupo Rede Bragantina for 10, Mococa for 3 and DME Distribution only for 1. According to the Law No. 9.074/1995, a very large number of concession permits for generation, transmission and distribution will end in 2015 and the situation regarding the

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6 The SUDENE program (The Superintendency for the Development of the Northeast) aims to reach development in the poor northeast of Brazil.
renewal of concession permits was mentioned as unclear (Tavares, 2010). Therefore, the information presented reflects the picture now and might be subject to change after 2015.

A detailed map of the actual situation of concession areas in the state is shown in Figure 9. The areas indicated in white are CEMIG’s concession area, while yellow indicates Energisa MG, red indicates Grupo Rede Bragantina, green indicates Mococa and blue indicates DME Distribution. CEMIG owns almost the whole area of concession in the state, with Energisa MG coming second. More information about the concessionaires in Minas Gerais and their participation in LPT is presented in Table 6 for comparison.

Figure 9: Map of concessionaires in Minas Gerais

Source: (FURNAS, 2011)
## Table 6: Concessionaires in Minas Gerais

<table>
<thead>
<tr>
<th>Concessionaires</th>
<th>CEMIG</th>
<th>Energisa MG(^7)</th>
<th>E.E. Bragantina</th>
<th>CPFL Mococa</th>
<th>DME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of Concession (km(^2))</td>
<td>567,740</td>
<td>16,331</td>
<td>3,453</td>
<td>2,078</td>
<td>544</td>
</tr>
<tr>
<td>Number of Customers</td>
<td>7,065,000</td>
<td>382,000</td>
<td>122,022</td>
<td>40,000</td>
<td>64,405</td>
</tr>
<tr>
<td>Number of connections for the period 2004-2011</td>
<td>285,000</td>
<td>32,820</td>
<td>3,883</td>
<td>535</td>
<td></td>
</tr>
<tr>
<td>Technology</td>
<td>Grid extension/PV</td>
<td>Grid extension</td>
<td>Grid extension</td>
<td>Grid extension</td>
<td></td>
</tr>
<tr>
<td>Average cost of connection (€)</td>
<td>2,428</td>
<td>2,374</td>
<td>2,423.08</td>
<td>3,192.72</td>
<td></td>
</tr>
<tr>
<td>Investment</td>
<td>RGR (€)</td>
<td>247,840,810</td>
<td>17,106,269</td>
<td>3,198,997</td>
<td>482,150</td>
</tr>
<tr>
<td></td>
<td>CDE (€)</td>
<td>291,751,385</td>
<td>20,728,773</td>
<td>3,763,527</td>
<td>559,750</td>
</tr>
<tr>
<td></td>
<td>State (€)</td>
<td>38,334,576</td>
<td>4,930,630</td>
<td>922,065</td>
<td>138,401</td>
</tr>
<tr>
<td></td>
<td>Concessionaire (€)</td>
<td>114,066,257</td>
<td>7,546,883</td>
<td>1,524,227</td>
<td>219,066</td>
</tr>
<tr>
<td></td>
<td>Total cost (€)</td>
<td>691,993,028</td>
<td>50,312,555</td>
<td>9,408,817</td>
<td>1,399,366</td>
</tr>
<tr>
<td></td>
<td>Share of subsidies (€)</td>
<td>47.70%</td>
<td>51.00%</td>
<td>49.80%</td>
<td>49.89%</td>
</tr>
</tbody>
</table>

Source: (ANEEL, 2009); (CEMIG, 2011a); (CPFL, 2011); (DME Distribution S/A, 2010); (Energisa MG, 2010; 2011a; 2011b) (Grupo Rede, 2010); (MME, 2011b)

---

\(^7\) Investment info and average cost of connection for Energisa Minas Gerais reflects the information for 26,215 connections.
The table shows that CEMIG’s area of concession almost covers the whole state, with services in every region. Though very small compared to CEMIG, Energisa MG serves a considerably larger area compared to other concessionaires. DME, along with Ijuí in the state of Santa Catarina, was one of the only two municipal concessionaires in the country (DME Distribution S.A., 2010). Serving only the municipality of Poços de Caldas, the company has reached universalization in its area of concession before the introduction of LPT. E.E. Bragantina and CPFL Mococa are two small companies that have small areas of concession and number of customers. As a result, they had small number of connections within LPT.

The difference between the costs of connections could be explained by a number of factors. The reason that the cost of connection for CPFL Mococa is the highest could be the size of the company. Since they did not make many connections, it could have been more expensive to supply materials. Given the fact that CEMIG has made connections in almost everywhere of the state, including areas where longer extensions were required, it is expected that the associated costs are higher. Energisa MG has the lowest cost of connection, because the concession area of the company is fairly homogenous, even though they have made large number of connections. The reason that Energisa MG received more subsidies could be the high number of connections for a company of this size, because LPT caused roughly a 10% increase in the number of customers of the company (Energisa MG, 2011a). Given the circumstances, a comparison between Energisa MG and CEMIG stood out to be more interesting, since Energisa MG was the second largest concessionaire in the state with considerably large number of connections compared to E.E. Bragantina and CPFL Mococa. This specific comparison is address in section 3.4.

3.2 Energisa Minas Gerais

Energisa Minas Gerais, formerly “Companhia Força e Luz Cataguases-Leopoldina”, was founded in the city of Cataguases in 1905. Energisa MG is a distribution company within the larger company Energisa, which has other distribution companies, generation facilities and other activities in the sector. The company has become a part of Energisa along with different companies in 2007. Energisa Generation mainly uses hydropower generation and is currently building 3 hydropower plants on Rio Grande. The stated goal of the company is to have 200 MW installed or under construction capacity from hydropower or other renewable resources by 2014 (Energisa Generation, 2009).

According to the information published in December 2010, Energisa MG serves 382,000 customers (Energisa MG, 2010). These customers are located in 66 municipalities, in a concession area of 16,331 km². 65 out of 66 municipalities are in the state of Minas Gerais, while Sumidouro in Rio de Janeiro is the only municipality that is located in another state. In the municipality of Sumidouro, 16.24% of the area of the municipality is attended by the Electrification Cooperative of Nova Friburgo, serving 595 households (ANEEL, 2005). Energisa MG has reported that it has sold 1,143.1 GWh of energy in 2010 (Energisa MG, 2010). The total length of the distribution lines owned by the company is 24,848 kilometers. Energisa Minas Gerais is expressed in numbers in Table 7.
All of the 65 municipalities in Minas Gerais under the responsibility of Energisa MG are in the Zona da Mata Region of the state. According to the second universalization plan handed to ANEEL by the company, there are no Indigenous areas in the area of concession of the company, but there are 45 protected natural areas that are distributed in 24 municipalities, corresponding to 6% of the area of concession of Energisa MG (ANEEL, 2005). After having previously participated in numerous rural electrification programs, such as Luz de Minas (Light of Minas), PRONAF and Luz no Campo (Light in the countryside) and having made 3,861 connections, the company has also participated in LPT (ANEEL, 2004b).

After the universalization law, every company had to determine a market potential. As the Census of 2000 was not updated by 2003, the company has determined the demand by taking vegetative growth of connections made in Luz no Campo program and billing information into account. Energisa MG reported to ANEEL that there were 6,704 households without electricity in its rural area by 2003 (ANEEL, 2004b).

### 3.2.1 Energisa Minas Gerais in LPT

Energisa MG is located in the Zona da Mata region of Minas Gerais. Municipalities in the region do not represent the best HDIs in Minas Gerais, but they could be considered as significantly higher if compared to the Northern part of the state. The rural area of the company consists of households that are not located far from the grid.

After having reported to ANEEL that the market demand of the company for the program was 6,704 households in late 2003, the company has determined an initial demand of 6,823 households in the beginning of the program (MME, 2011b). The final number of connections reported by the company in June was 27,098 (Energisa MG, 2011a).

Energisa Minas Gerais has divided its area of concession in 5 regions for the implementation of LPT. According to the responsible at the company, 30 people in management and 120 people in the field work for the program. This number was a total of 400 when the company had a peak of connections in the year 2006. The year 2006 was the same for all companies with large numbers of connections and Energisa MG mentioned that there were problems with the supply of materials and prices increased dramatically, as high as 70%, having negative impacts on the company (Energisa MG, 2011b).

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**Table 7: Energisa Minas Gerais in numbers**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of attended municipalities</td>
<td>66</td>
</tr>
<tr>
<td>Area of concession (km²)</td>
<td>16,331</td>
</tr>
<tr>
<td>Attended population</td>
<td>979,000</td>
</tr>
<tr>
<td>Number of customers</td>
<td>382,000</td>
</tr>
<tr>
<td>Total sold energy (GWh)</td>
<td>1143.1</td>
</tr>
<tr>
<td>Number of employees</td>
<td>538</td>
</tr>
<tr>
<td>Number of employees (own and outsourced)</td>
<td>663</td>
</tr>
<tr>
<td>Customers/Number of employees (own and outsourced)</td>
<td>577</td>
</tr>
<tr>
<td>Annual duration of outages in hours</td>
<td>12.53</td>
</tr>
<tr>
<td>Annual frequency of outages in number of times</td>
<td>13.07</td>
</tr>
<tr>
<td>Number of substations</td>
<td>45</td>
</tr>
<tr>
<td>Installed capacity in substations (MVA)</td>
<td>867</td>
</tr>
<tr>
<td>Number of distribution transformers</td>
<td>54,348</td>
</tr>
<tr>
<td>Length of the total distribution lines (km)</td>
<td>24,848</td>
</tr>
</tbody>
</table>

Source: (Energisa MG, 2010)
The number of connections and its share in the total number of new connections made in a year is important. For example, it is beneficial for Energisa MG to take part in LPT program because the subsidies and low interest rate loans help the company to eliminate the expenses that would lead to an increase in the electricity price, as all concessionaires have different prices of electricity. If there had not been for LPT, the connections would have led to increased price of energy for all consumers of Energisa by 10% (Energisa MG, 2011b).

Energisa MG has presented contract details that were signed separately with ELETROBRÁS and the state of Minas Gerais. According to the information, 8 contracts and additional 3 prolongation agreements were signed. The company has divided the program in two phases, the first phase between 2004 and 2007 and the second phase between 2007-2011. The contracts with ELETROBRÁS were made to connect 23,565 households, while 3,533 connections were specified in the contracts with the state of Minas Gerais (Energisa MG, 2011a). More information about the contracts is presented in Table 8. Prolongation 061/2008 will be extended to December 2011.

Table 8: Agreements signed by Energisa MG for LPT

<table>
<thead>
<tr>
<th>Name</th>
<th>Date of Signature</th>
<th>Phase</th>
<th>Foreseen connections</th>
<th>Expected end</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECFS-085/2005</td>
<td>06.07.2005</td>
<td>1</td>
<td>6,033</td>
<td>April 2006</td>
<td>Finished</td>
</tr>
<tr>
<td>ECFS-085-A/2005</td>
<td>17.01.2006</td>
<td>1</td>
<td>1,820</td>
<td>December 2006</td>
<td>Finished</td>
</tr>
<tr>
<td>ECFS-085-B/2006</td>
<td>16.10.2006</td>
<td>1</td>
<td>122</td>
<td>December 2006</td>
<td>Finished</td>
</tr>
<tr>
<td>ECFS-085-C/2007</td>
<td>08.05.2007</td>
<td>1</td>
<td>989</td>
<td>July 2007</td>
<td>Finished</td>
</tr>
<tr>
<td>ECFS-191/2007</td>
<td>11.09.2007</td>
<td>2</td>
<td>14,001</td>
<td>December 2010</td>
<td>In Progress</td>
</tr>
<tr>
<td>Prolongation until December 2010</td>
<td>-</td>
<td>2</td>
<td>600</td>
<td>December 2011</td>
<td>In progress</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td><strong>23,565</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Date of Signature</th>
<th>Phase</th>
<th>Foreseen connections</th>
<th>Expected end</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agreement 018/2006</td>
<td>20.09.2006</td>
<td>1</td>
<td>555</td>
<td>August 2007</td>
<td>Finished</td>
</tr>
<tr>
<td>Agreement 018/2006</td>
<td>29.08.2007</td>
<td>1</td>
<td>37</td>
<td>March 2008</td>
<td>Finished</td>
</tr>
<tr>
<td>Agreement 061/2008</td>
<td>23.12.2008</td>
<td>2</td>
<td>1,823</td>
<td>December 2009</td>
<td>In Progress</td>
</tr>
<tr>
<td>Prolongation 061/2008</td>
<td>27.07.2010</td>
<td>2</td>
<td>650</td>
<td>July 2011</td>
<td></td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td><strong>3,533</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: (Energisa MG, 2011a)
Annual connections by Energisa MG until the end of 2010 in LPT program are presented in Table 9. Detailed information about the recent connections in 2011 is shown in Figure 10.

Table 9: Annual connections in LPT by Energisa MG

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connections</td>
<td>85</td>
<td>2,552</td>
<td>6,372</td>
<td>1,902</td>
<td>7,314</td>
<td>4,672</td>
<td>2,889</td>
</tr>
</tbody>
</table>

Source: (Energisa MG, 2011a)

Energisa MG does not have any individual systems or isolated grids, so all of its customers are connected to the national grid. So, there is no new renewable energy-based system used in the program. According to the company, 42,699 utility poles and 4,900 kilometers of grid extension have been built and 18,186 distribution units were installed in LPT. The overall investment was reported to be € 50,312,554. The connections in the first phase cost € 2027.26 /connection, while it cost € 2721.20 /connection in the second phase (Energisa MG, 2011a). The harder to reach areas were universalized at the end, leading to a price difference, along with the unstable cost of materials in the market. An important point to mention here is that an average connection in an urban area costs only € 91.16 for Energisa MG, proving how distances and rural conditions affect the projects and economics of universalization (ANEEL, 2004b).

The final number of total connections to be made until the end of 2011 was expressed as 27,098 by the company during the visit in June 2011. According to Energisa MG, 10,024 beneficiaries were connected in the first phase of the program. The total cost of this phase was reported to be € 19,274,180. The second phase cost € 31,038,375, taking electricity to 16,191 beneficiaries (Energisa MG, 2011a). Detailed information about the each phase of the program is presented in Table 10.

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8 Numbers refer to the second phase of the program.
Table 10: Technical information about LPT by Energisa MG

<table>
<thead>
<tr>
<th></th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connections</td>
<td>10,024.00</td>
<td>16,191.00</td>
<td>26,215.00</td>
</tr>
<tr>
<td>Installed poles</td>
<td>15,630.00</td>
<td>27,069.00</td>
<td>42,699.00</td>
</tr>
<tr>
<td>Grid extension (km)</td>
<td>2,146.00</td>
<td>2,754.00</td>
<td>4,900.00</td>
</tr>
<tr>
<td>Distribution units</td>
<td>6,275.00</td>
<td>11,911.00</td>
<td>18,186.00</td>
</tr>
<tr>
<td>Installed Potential (MVA)</td>
<td>33.28</td>
<td>76</td>
<td>109.28</td>
</tr>
<tr>
<td>Total Investment (Million €)</td>
<td>19.27</td>
<td>31.04</td>
<td>50.31</td>
</tr>
</tbody>
</table>

Source: (Energisa MG, 2011a)

The financial information regarding the program by Energisa MG is presented in Table 11. 51% of the program has been financed with subsidies, while 34% came from low interest rate loans and 15% consisted of own resources (MME, 2011b).

Table 11: Allocation of resources for LPT by Energisa MG

<table>
<thead>
<tr>
<th>Resources</th>
<th>Amount €</th>
<th>Percentage</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGR</td>
<td>17,106,269</td>
<td>34.00%</td>
<td>Loan</td>
</tr>
<tr>
<td>CDE</td>
<td>20,728,773</td>
<td>41.20%</td>
<td>Subsidy</td>
</tr>
<tr>
<td>State</td>
<td>4,930,630</td>
<td>9.80%</td>
<td>Subsidy</td>
</tr>
<tr>
<td>Energisa MG</td>
<td>7,546,883</td>
<td>15.00%</td>
<td>Own funds</td>
</tr>
<tr>
<td></td>
<td>50,312,555</td>
<td>100.00%</td>
<td></td>
</tr>
</tbody>
</table>

Source: (Energisa MG, 2011a; 2011b)

Until May 2011, there were 7023 beneficiaries, who had outstanding invoices. 575 clients, representing 2.39% of the total beneficiaries in the program, have been disconnected since the start of the program due to unpaid bills. Reported average monthly consumption per beneficiary in the program is 97.4 kWh (Energisa MG, 2011a). The company has completed registrations for new connections in March 2011 before the closure of the program, but has expressed interest in prolongation of LPT to meet the demand that it specified as “more than the contracted number”.

One of the problems mentioned by the company was the existence of contractual problems in the beginning of the program, but then they pointed out that the rest of the process was without any major obstacles. The prices usually did not reflect the time when the contracts were signed and there were uncontracted additional connections. This means that the company has paid for these connections from its own resources.

Large cities are important for concessionaires. Residents of large cities are profitable, since they do not incur in any expenses living in an already developed infrastructure and they have higher consumption of electricity, thus more expensive electricity bills. Energisa MG has mentioned that the lack of a large city in their area of concession was a problem and they demanded larger subsidies in contracts to make sure they have financial means to conduct the program without increasing the price of electricity.

Energisa MG has not prioritized any projects, because HDIs and conditions within the concession area of the company are similar. Therefore, the company has started the program in all of its areas in the beginning of the program, but firstly completed areas that had logistical advantages. It is possible to say that the area of concession of the company is uniform. The company has reported during the meeting in Cataguases that they have connected 4 households per kilometer of grid that is extended (Energisa MG, 2011b).
3.3 CEMIG

One of the largest energy companies in South America, CEMIG, was founded in 1952. The company works in the sectors of generation, transmission and distribution. It consists of 58 companies and 10 consortia. Headquartered in Belo Horizonte, Minas Gerais, CEMIG was reported to have businesses in 18 Brazilian states, the Federal District and Chile, where it has transmission facilities. The company also have activities in natural gas and telecommunication sectors.

Having a very international character, CEMIG is owned 51% by the state of Minas Gerais, with the rest being shared by 114,600 shareholders in 44 different countries. The 51% share means that the state of Minas Gerais has the major influence on decision-making and largely shapes the policy of the company. The company has shares in Sao Paulo, New York and Madrid stock exchanges, with a stated value of € 7.814 billion. CEMIG controls 12% of the Brazilian energy market, serving approximately 18 million people living in 774 municipalities of Minas Gerais with its 475,000 kilometers of distribution lines and decentralized systems (CEMIG, 2011a).

Total reported generation capacity of CEMIG is 6,896 MW with 67 power plants. The electricity generated is carried with 8,700 kilometers of transmission lines. Having been listed in sustainability indexes repeatedly, such as Dow Jones and Sao Paulo, the company was reported to have 96.5% of its installed capacity from hydropower (CEMIG, 2011a). CEMIG is usually known for its innovative approach and research and development focused structure. Different innovation projects are undertaken by the company in different fields, including biodiversity, renewable energies, electricity market and customer care (CEMIG, 2011c).

CEMIG is one of the pioneers in the area of renewable energies in Brazil. Along with COELBA (Electricity Company of Bahia State), CEMIG is considered to be one of the most experienced companies in PV systems in the country. In addition to thousands of individual systems, the company announced in its 2010 annual report that it is planning to construct a grid connected 3 MW PV powerplant in Minas Gerais. For 2014 World Cup, CEMIG will cover the roof of the legendary stadium Mineirão, as well as Mineirinho and a gymnasium with PV cells that would provide 1.4 MW and cost € 13 million (CEMIG, 2011a). It is useful to remind that CEMIG owns a training center in Sete Lagoas in Minas Gerais, where it continues its experimental and educational activities about the PV technology.

The company also holds shares in Praia de Parajuru (28.8 MW), Praia do Morgado (28.8 MW) and Volta do Rio (42 MW) wind farms. It was reported by the company that these wind farms prevent 146,000 t CO₂ to be emitted to the atmosphere (CEMIG, 2011a). CEMIG mapped the wind power potential of the state in 2010, which is an indication that the company is interested to increase the share of wind power in its energy mix in the future. This is not surprising after the energy crisis in Brazil in 2001, which raised questions about an energy mix that is almost totally dependent on rainfalls.

CEMIG has been very active in small hydropower technology. Having started the Minas SHP Program in 2004, the company aims to construct 400 MW total capacity of small hydropower plants. The program was created to study the implementation of this technology in every aspect, including environmental concerns financial conditions and technologies. In 2010, there were 4 projects in the final phase that accounted for 44 MW of capacity (CEMIG, 2011a).

CEMIG is interested to use biomass in order to diversify its energy mix and contribute to the security of energy supply in Brazil. The company has stated that it has been working with sugar/alcohol industry to use the byproducts for electricity generation. CEMIG is interested in using the gases that are created during the carbonization of wood in charcoal production. According to the annual report of 2010, a biomass power plant with 43 MW has been concluded to supply power to the grid in 2011. CEMIG signed a contract with the Belo Horizonte City Hall to use the biogas in a sanitary landfill. The company expects to generate 4.9 MW a year between 2011 and 2014, which will come from the 21 million tones of garbage that was dumped in the area for 20 years until 2007 (CEMIG, 2011a).
Predominantly Hydropower, the representation of major power plants of CEMIG in Minas Gerais is shown in Figure 11. Blue represents hydropower, brown thermal and green (in the center), wind.

Figure 11: Major power plants owned by CEMIG

Source: (CEMIG, 2011a)

### 3.3.1 CEMIG in LPT

The way that CEMIG handles the LPT program is well different from other companies, firstly because of the financial strength of the company, as well as the high level of experience gained over the years. Along with ELETROBRÁS, CEMIG determined the potential market for connections within the program. This happened in six steps since the introduction of the program (CEMIG, 2011b):

- Just after the universalization law, ELETROBRÁS has determined a market potential of 105,000 connections, based on the 2000 census.
- Between October 2003 and February 2004, CEMIG studied the market and determined a demand of 115,000 connections.
- After the completion of a more detailed study in June 2004, the market potential for new households and farms were identified as 176,000.
- Finished turnkey projects created a further demand and the potential has been reported to rise to 270,000 households.
- Technical Assistance Enterprise and Rural Extension of Minas Gerais (Emater-MG) and CEMIG have reported that upon completion of projects in the program, the final number of households attended will be 285,000.

**Luz Para Todos Phase 1 – LPT 1**

The first part of the program took place between 2004 and 2007. With 190,000 connected households, it was the phase where most of the connections were made. This was largely achieved by 55,000 kilometers of extension of the grid and installation of 443,000 utility poles (CEMIG, 2011b). For households in remote areas, 2500 individual PV systems were installed, representing 0.88% of the total connections by CEMIG in the program.

CEMIG has declared a budget of € 737,975,342.9 for the first phase of the program (CEMIG, 2011b). The company divided its concession area in 4 regions and created responsible teams for each region. The headquarters of CEMIG in Belo Horizonte has a department for LPT, which acts as the coordinator of
the program and ensures a smooth process of implementation. These 4 regions and their locations are shown in Figure 12. The white parts are the areas of concession of other concessionaires.

Figure 12: Organizational regions for LPT Phase 1 by CEMIG

Source: (CEMIG, 2011b)

**Luz Para Todos Phase 2 – LPT 2**

LPT phase 2 started after 2007, upon discovery of the rising demand and vegetative growth, and lasted until the end of 2010. In this phase of the program, CEMIG realized 70,000 connections. The total budget of the phase was reported to be €347,282,514 (CEMIG, 2011b). All connections in this phase were made by grid extension. CEMIG has realized certain part of the connections by subcontractors.

According to the information received from the directorate of LPT at CEMIG, the company itself connected 26,250 households in 205 municipalities in this phase. Subcontractors also connected 43,750 households in 569 different municipalities with electricity. In total, 70,000 households were connected with 21,000 kilometers of grid extension and 170,000 utility poles (CEMIG, 2011b). CEMIG followed a more complicated division of the area of concession for the implementation of this phase. The company created 12 lots. 10 lots with distributed regions were attended by CEMIG, while the rest was divided between two subcontractors. In Figure 13, it can be observed that there are two main regions, light beige and turquoise, allocated for subcontractors. The remaining region, consisting of 10 different areas, was handled by CEMIG. EI stands for Empreitada Integral in Portuguese, meaning that the work is fully outsourced. It is worthy to mention that the decisions about the method of attendance for the outsourced connections were reached by CEMIG, not the subcontractors.
Luz Para Todos Phase 3 – LPT 3

The third phase of the program in CEMIG started in 2011, with the stated goal of 25,000 connections. According to the company, these 25,000 households are located in 774 municipalities. The total cost of connections was estimated to be € 154,106,616 (CEMIG, 2011b). Grid extension was chosen as the sole method of attendance for this phase.

For the final phase of the program, CEMIG divided its area of concession in 3 parts as shown in Figure 14. The white areas are either the parts of the state that are served by other concessionaires, or they were already universalized.
According to CEMIG, by 24th of May 2011, there were 264,855 connections realized in the program. The beneficiaries were located in 774 municipalities, meaning that 93% of the program had been completed. This means that there were still 20,145 households to be connected before the closure of the program. The company will meet this demand by grid extension (CEMIG, 2011e). The total investment in the program is announced as € 1,267,581,177 (CEMIG, 2011b).

CEMIG informed that 81% of the municipalities attended had HDIs lower than the average of Minas Gerais state (0.773) (CEMIG, 2011b). Upon completion, 233,800 households that live in municipalities with HDIs below the average of the state will receive electricity for the first time. The total investment for these connections will be € 1,040,111,130, representing 82% of the total investment in LPT. Table 12 summarizes this information (CEMIG, 2011b).

Table 12: Municipalities in LPT with HDIs lower than state average

<table>
<thead>
<tr>
<th>Municipalities with HDIs lower than the average of Minas Gerais (0.773)</th>
<th>Share in the program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipalities</td>
<td>633</td>
</tr>
<tr>
<td>Target</td>
<td>233,800</td>
</tr>
<tr>
<td>Attended Households (06/05/2011)</td>
<td>221,111</td>
</tr>
<tr>
<td>Investment (million €)</td>
<td>1040.11113</td>
</tr>
</tbody>
</table>

Source: (CEMIG, 2011b)
As previously mentioned, the regions with the lowest HDIs in Minas Gerais are Rio Doce, Mucuri, Jequitinhonha and the North. They show signs of underdeveloped areas and are home to many poor families. CEMIG informed that 332 municipalities were within the mentioned regions, where 157,991 attended households were located. The demand in the area represents the 59% of the total demand of LPT in Minas Gerais. This information is important to understand that there is a strong relation between the HDI and electrification. More information about connections in these regions is shown in Table 13.

Table 13: LPT in Rio Doce, Mucuri, Jequitinhonha and North regions

<table>
<thead>
<tr>
<th>Rio Doce, Mucuri, Jequitinhonha and North</th>
<th>Share in the program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipalities</td>
<td>332</td>
</tr>
<tr>
<td>Target</td>
<td>166,978</td>
</tr>
<tr>
<td>Attended Households (06/05/2011)</td>
<td>157,991</td>
</tr>
<tr>
<td>Investment (million €)</td>
<td>742.7504775</td>
</tr>
</tbody>
</table>

Source: (CEMIG, 2011b)

IDENE – Instituto de Desenvolvimento do Norte e Nordeste de Minas Gerais (Institute of Development of North and Northeast of Minas Gerais) was founded in 2002 to promote development in the less developed regions of Jequitinhonha, Mucuri and North of the state. It creates plans and takes actions to reach development in the state, while supervising the activities and orientating other actors in the process. The IDENE regions are served by CEMIG, where the company connected 114,477 households until the 6th of May in 2011. 4% of the total demand in IDENE regions still has not been met. Table 14 presents the situation for the regions that are in responsibility of IDENE (CEMIG, 2011b).

Table 14: LPT in IDENE regions

<table>
<thead>
<tr>
<th>IDENE</th>
<th>Share in the program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipalities</td>
<td>188</td>
</tr>
<tr>
<td>Target</td>
<td>119,411</td>
</tr>
<tr>
<td>Attended Households (06/05/2011)</td>
<td>114,477</td>
</tr>
<tr>
<td>Investment (million €)</td>
<td>530.9081438</td>
</tr>
</tbody>
</table>

Source: (CEMIG, 2011b)
Table 15 presents a summary of the program in CEMIG in numbers.

### Table 15: Summary of LPT at CEMIG

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility poles</td>
<td>443,085</td>
<td>170,000</td>
<td>60,000</td>
<td>673,000</td>
</tr>
<tr>
<td>Transformers</td>
<td>104,652</td>
<td>44,642</td>
<td>17,800</td>
<td>167,000</td>
</tr>
<tr>
<td>Kilometers of grid</td>
<td>55,624</td>
<td>21,000</td>
<td>7,500</td>
<td>84,000(*)</td>
</tr>
<tr>
<td>Consumers</td>
<td>190,426</td>
<td>70,000</td>
<td>25,000</td>
<td>285,000</td>
</tr>
<tr>
<td>Total costs (€)</td>
<td>0.768 bil</td>
<td>345.546 mil</td>
<td>154.107 mil</td>
<td>1.268 bil.</td>
</tr>
<tr>
<td>Average cost for electrification (€)</td>
<td>4,034.555</td>
<td>4,935.753</td>
<td>6,164.265</td>
<td>4,416.999</td>
</tr>
<tr>
<td>Average distance for electrification</td>
<td>0.292 km</td>
<td>0.300 km</td>
<td>0.300 km</td>
<td>0.294 km</td>
</tr>
<tr>
<td>Number of connections</td>
<td>190,426</td>
<td>70,953</td>
<td>1,961</td>
<td>263,340</td>
</tr>
</tbody>
</table>

Reference: 10/05/11

(*) Corresponds to 24% of the total length of rural grid of CEMIG

Source: (CEMIG, 2011b)

According to the official information obtained from the Ministry of Mines and Energy, the total investment from CEMIG on LPT was reported as € 691,993,028 (MME, 2011b). This information reflects the sum of the investments according to initial agreements with CEMIG. It is known that the company occasionally used its own resources to finance projects, this could be the reason that the total number reported by the company is larger. For example, CEMIG financed the PV systems in the program from its own resources and holds the ownership of the installed systems. Keeping the ownership of the systems is useful to track their performance and carry out maintenance activities with professionals who are familiar with the systems. Since it is not possible to access the copies of original agreements, the terms and specific information could not be obtained.

More information about the data received from the Ministry is in Table 16.

### Table 16: Allocation of resources for LPT by CEMIG

<table>
<thead>
<tr>
<th>Resources</th>
<th>Amount (€)</th>
<th>Percentage</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGR</td>
<td>247,840,810.04</td>
<td>35.82%</td>
<td>Loan</td>
</tr>
<tr>
<td>CDE</td>
<td>291,751,384.79</td>
<td>42.16%</td>
<td>Subsidy</td>
</tr>
<tr>
<td>State</td>
<td>38,334,576.32</td>
<td>5.54%</td>
<td>Subsidy</td>
</tr>
<tr>
<td>CEMIG</td>
<td>114,066,256.65</td>
<td>16.48%</td>
<td>Own funds</td>
</tr>
<tr>
<td></td>
<td>691,993,027.79</td>
<td>100.00%</td>
<td></td>
</tr>
</tbody>
</table>

Source: (MME, 2011b)

According to this information, 52.3% of the total costs of the projects were either financed by CEMIG’s funds or taken as a low interest loan in RGR. Taking the extra costs that were covered by own resources of CEMIG, the company’s profile in the program is different than smaller companies. The percentage of the state support is lower for CEMIG with 5.54%, but the use of CDE (Energy Development Account) funds is higher than any other concessionaire. The reason for this could be providing more state resources for smaller concessionaires.
**Luz no Saber (Light for Knowledge Program)**

Luz no Saber is a rural school electrification sub-program by CEMIG within LPT in Minas Gerais. It consists of PV systems that are suitable for use in the most remote communities, thanks to the good availability of solar resources in the state, along with grid extension.

Luz no Saber provided electricity and potable water to 1200 rural schools that did not have these fundamental elements of life by the beginning of 2003. 500 out of 1200 connections were reported to use PV systems, with basic installation of 720-2000Wp PV panels, lighting, TV, VCR, satellite dish and water pumping facilities (Diniz et al., 2006).

CEMIG owns the PV systems and is responsible for their maintenance. The municipalities that benefit from the program only pay the corresponding tariff to CEMIG.

The working principle of Luz no Saber is as follows:

- The municipalities contact CEMIG’s local office
- The local office compares the grid connection with PV connection and chooses the system that costs less
- The engineering office then designs and monitors the PV systems
- In case of failure, a responsible calls CEMIG and gives the specific number of the system, which helps CEMIG to locate the system by GPS
- The regional office of CEMIG takes care of the payments
- Finally, CEMIG invites an employee from the municipality to its PV Training Centre to inform them about the systems and preventive maintenance activities.

The program provides lighting, communication and improved educational conditions for communities. Considering the fact that schools are a gathering place for locals, the arrival of electricity does not only improve day and night educational activities, but also has positive impacts on rural social life.

### 3.4 Comparison of CEMIG with Energisa MG in LPT

CEMIG and Energisa MG are two companies of different sizes. CEMIG is a very large company, while Energisa MG is much smaller. The areas of concession of the two companies are different in terms of size, population and characteristics. CEMIG serves almost the whole Minas Gerais, having services in all regions with different characteristics, while Energisa MG only serves municipalities in the Zona da Mata region. Undoubtedly, this creates a large difference between the client profile of Energisa MG and CEMIG. Energisa MG, serving only the municipalities at a specific relatively developed region, has a very uniform customer profile and no reported challenging conditions in its area of concession. The company serves small cities and other smaller settlements with almost no consumer that was considered “remote” by the company. This is why Energisa MG did not consider any attendance method other than grid extension. CEMIG has a large spectrum of clients, geographical conditions and settlements. Living conditions and HDIs vary greatly and almost every region has its specific problems that require previous knowledge to be dealt with. Most of these difficulties created favourable conditions for the use of PV systems in LPT by CEMIG. Information about CEMIG and Energisa MG is presented in Table 17 for easier comparison.
Table 17: Comparison between Energisa MG and CEMIG

<table>
<thead>
<tr>
<th></th>
<th>CEMIG</th>
<th>Energisa MG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of concession (km²)</td>
<td>567,740</td>
<td>16,331</td>
</tr>
<tr>
<td>Characteristics of the concession area</td>
<td>Conditions depend on the region</td>
<td>Homogenous, Relatively higher HDIs</td>
</tr>
<tr>
<td>Number of customers</td>
<td>7,065,000</td>
<td>382,000</td>
</tr>
<tr>
<td>Significant number of minorities</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Large cities in the area of concession</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Number of connections in LPT</td>
<td>285,000</td>
<td>32,820</td>
</tr>
<tr>
<td>Used technologies in LPT</td>
<td>Grid extension/PV</td>
<td>Grid extension</td>
</tr>
<tr>
<td>LPT connections/Total number of customers</td>
<td>4%</td>
<td>8.5%</td>
</tr>
<tr>
<td>Average cost of connection (€)</td>
<td>2,428</td>
<td>2,374</td>
</tr>
<tr>
<td>Share of subsidies</td>
<td>47.70%</td>
<td>51%</td>
</tr>
<tr>
<td>Proritized Connections</td>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>

Source: (CEMIG, 2011a); (Energisa MG, 2010; 2011a; 2011b); (MME, 2011b)

Major obstacles experienced in the electrification process were the geographical and natural problems encountered. Unlike Energisa MG, CEMIG had to serve clients in places that were hard to reach or located in protection areas that prevented the company from conducting work normally. Some of the households are located in such places that the only possible way to electrify them was decentralized systems, since extension and maintenance of the grid would be impossible. This was not the case for Energisa MG, which did all of its connections by extending the grid and connecting the households to the national interconnected system. Having extensive knowledge of the PV systems, CEMIG was able to manage the program successfully, but it is not clear if it would be possible for Energisa MG or any other smaller company who never worked with such systems. Figure 15 show CEMIG’s employees trying to extend the grid in LPT under very hard conditions due to rain and flood in the municipality of Sao Francisco in March 2011.

Figure 15: Experienced difficulties due to heavy rain in Sao Francisco region in March 2011

Source: (CEMIG, 2011d)

CEMIG has considerable number of Indigenous and Quilombola settlements, while Energisa MG has none. These communities, especially Quilombolas, live in places that are very hard to reach and conduct work at. Energisa MG did not have such remote communities in its area of concession, while CEMIG had to electrify them after universalization became obligatory. These consumers are usually very poor and their consumption of electricity is low, making them not profitable to be connected by the company.
CEMIG has numerous large cities in its area of concession and Energisa MG does not. Large cities are usually considered easily reachable by concessionaires, as they do not require much investment like rural areas. The infrastructures in the cities are good and usually customers consume a considerable amount of electricity, which will return as profit to the companies. All expenditure of the company will affect its tariff and increase the price of energy and this amount is usually gathered from the consumers in big cities. So, CEMIG can benefit from having large cities like Belo Horizonte, Uberlandia and some others, while Energisa MG does not serve any large city in its area of concession. This affects the income of the company in and limits the planned projects.

Maintenance of the grid is a very important point to be mentioned. CEMIG is spread all over the state, it has extensive abilities and knowledge to conduct such activities. It also helped CEMIG to have successful rural electrification programs by solar energy in the past, using its well-distributed infrastructure to ensure sustainability of the systems. This, of course, has positive impacts on the company’s capacity to offer reliability in the systems installed.

The size of the company has strong impacts on the program and this is mainly because of the related financial power. Every year, CEMIG connects roughly 250,000 new consumers, almost the total number of consumers connected within LPT by the company since the beginning of the program. This means that the financial impacts of the program on the company were probably not significant. Since individual systems were not incentivised, CEMIG financed the PV systems that were used in the program. It is unknown if Energisa MG would consider using individual systems if there was enough subsidies offered.

When looking at Table 5, we can see that 51% of the projects by Energisa MG were financed with subsidies, while it was 47.7% for CEMIG’s case, though there were PV systems installed without additional support from the authorities (MME, 2011b). The subsidies were important for Energisa MG, as they mentioned that they demanded more subsidies in the program and experienced difficulties with increased prices in 2006. Even though the cost of connection was cheaper for Energisa MG, it should be noted that the number of households connected represent a significant portion in the number of total consumers of the company. This could be one of the reasons that the company needed more subsidies, undertaking a large project for its size.

The largest owner of shares in CEMIG is the state of Minas Gerais. This gives CEMIG a social role and determines the company’s attitude in certain situations. The existence of the state influences CEMIG to take part in social programs and having a special interest in rural electrification to increase the quality of life in the state. So, the decisions of CEMIG are not solely based on profit, which is usually the case for a totally private company like Energisa MG. This existence also has a negative effect, which is the politics to be involved. The exact impacts of politics on the policies of the company are not known, but it is perceived by the author that the low number of PV systems built comparing to the foreseen number in the beginning of the program is the outcome of political influences from the public along with other factors. Dissatisfaction with PV systems, mainly coming from capacity issues, and the desire to be electrified by the grid created a public pressure that favoured the extension of the grid for cases where PV systems could be employed. Considering the fact that the state is the largest shareowner in CEMIG, reactions from smaller authorities might have influenced the state to support grid extension to reduce this public pressure.

In conclusion, the differences between the two companies are not solely related to their sizes, but also their areas of concession. The larger area of concession of CEMIG shows a great diversity, which required different ways to conduct the program, including the use of PV systems. Energisa MG has an area of concession that there are not large differences between municipalities in terms of characteristics. Therefore, for Energisa MG, there was no need to consider other technologies or plan the implementation according to HDIs. The company had only one aim, electrifying all of their area of concession by the deadlines in the fastest and the most economic way possible.
4 Decentralized Renewable Technologies in Luz Para Todos

In this chapter, renewable energy technologies used in LPT are discussed. The need to use such systems in rural electrification programs is explained. Then, the regulations about the use of renewable energy technologies for individual systems and mini-grids within LPT context are discussed. Since CEMIG was the only concessionaire who used renewable energy in LPT in Minas Gerais, the whole process of electrification by PV systems from the determination of local energy potentials to system sizing is included.

4.1 Renewables in Rural Electrification

Rural electrification is not an easy task. It requires larger investments and expertise to deal with challenging conditions, which do not exist in urban areas. Grid extension is a traditional way to provide electricity to people in urban areas, where it is feasible to make connections with only tens or hundreds of meters of extension in most of the cases. Besides, the interconnected grid is constantly fed with energy from power plants all over the country, which gives reliability to the system. The situation is different in rural areas, where households are distributed and they are either far from the grid, or far from each other to be feasible to make a grid extension. There are also remote communities or households that are too far to reach and the only viable solution in these cases is the use of minigrids or individual systems, as considered in LPT handbooks. Legal restrictions in conducting work in protected areas also makes decentralized options more favourable over grid extension.

The lack of economic activity in most rural places also stands out as a barrier for grid extension. Since the consumption will not be much, renewable individual systems became feasible for concessionaires to meet the basic needs of these consumers. An example of a remote consumer with a PV system provided by CEMIG is shown in Figure 16.

![Figure 16: A consumer located in an isolated place with CEMIG’s PV system](Source: (CEMIG, 2011d))
Decentralized renewable energy technologies, such as PV, small wind, small hydropower, bioenergy and fuel cells emerge as a competitive solution for these cases. Except bioenergy and fuel cells, these technologies do not need fuel, they harvest the energy that the nature offers us for free. They require less maintenance, they do not cause pollution and global warming and they are not affected by fluctuating prices in the market as much as conventional systems, meaning that they are more stable in terms of supply. But, they have drawbacks as any system. Intermittent supply is the major problem related to these technologies. The reason for this is that a wind turbine works when the wind blows and a PV panel works when there is sunlight. This problem is solved to a certain extent by using batteries and/or hybrid systems, but is still existent. Another drawback of these systems is that they still require large investments. Even though PV and small wind technologies are becoming cheaper, fuel cells are still very expensive to become feasible because of their content of precious materials. Small hydropower stands as a trustable way for power generation, but requires construction work. Considering that PV was the only technology to be implemented in Minas Gerais, this thesis focuses on the use of this technology.

![Figure 17: A rural family electrified by CEMIG’s SIGFI13 system](image)

Source: (CEMIG, 2011d)

### 4.2 Decentralized Systems for Power Generation

Decentralized systems were previously used in rural electrification in Brazil. Traditionally, PV was the most used renewable technology in decentralized generation in the country. It is estimated that there were 40,000 PV systems built throughout the country (IEI, 2009).

It is important that decentralized systems provide continuous energy to consumers. Good monitoring and maintenance are considered fundamental to ensure sustainability of the systems. Taking PRODEEM as example, many systems were either installed incorrectly or were out of service shortly due to lack of skilled technicians and maintenance (Borges Neto et al., 2010). This created a demand for regulating decentralized connections to make sure that the consumers receive stable energy supply with good quality.
4.2.1 Individual Systems

ANEEL has issued the resolution No. 083/2004 to define the criteria to be followed by concessionaires when making individual connections. Until this resolution, there was no legal framework that regulated the use of stand-alone, also known as individual, systems. The decree covers wind energy, solar energy, small hydropower and biomass. The most important point in the decree is that it introduced a system called SIGFI - Sistema Individual de Geração de Energia Elétrica com Fonte Intermittente, meaning Individual System for Generation of Electrical Energy with Intermittent Source. This method categorizes systems to be built regarding their specifications and obliges the concessionaires to install one of these systems to ensure sustainable supply of electricity.

SIGFI takes different aspects into account to provide continuous energy to consumers. There are 5 SIGFIs: SIGFI13, SIGFI30, SIGFI45, SIGFI60 and SIGFI80, with the number at the end referring to the monthly guaranteed availability of energy in kilowatthours. Each SIGFI should also meet the criteria for supplying reference daily consumption (Wh/day), minimum autonomy in days without any flow of energy from the primary resource and minimum available potential (W). If desired, the concessionaires are permitted to use SIGFIs with larger monthly guaranteed availability of energy than 80kWh, but they have to ensure that the systems have 2 days of minimum autonomy. SIGFIs and their specifications are shown in Table 18 (ANEEL, 2004c).

<table>
<thead>
<tr>
<th>Type of system</th>
<th>Reference for daily consumption (Wh/day)</th>
<th>Minimum autonomy (days)</th>
<th>Minimum Availability of Potential (W)</th>
<th>Minimum Monthly Availability (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGFI13</td>
<td>435</td>
<td>2</td>
<td>250</td>
<td>13</td>
</tr>
<tr>
<td>SIGFI30</td>
<td>1000</td>
<td>2</td>
<td>500</td>
<td>30</td>
</tr>
<tr>
<td>SIGFI45</td>
<td>1500</td>
<td>2</td>
<td>700</td>
<td>45</td>
</tr>
<tr>
<td>SIGFI60</td>
<td>2000</td>
<td>2</td>
<td>1000</td>
<td>60</td>
</tr>
<tr>
<td>SIGFI80</td>
<td>2650</td>
<td>2</td>
<td>1250</td>
<td>80</td>
</tr>
</tbody>
</table>

Source: (ANEEL, 2004c)

The resolution does not only define the SIGFIs to be used, but also determines other criteria to be met, such as the supply of only alternative current, billing information and disruption. It obliges the use of materials that meet the norms defined by institutions, such as the National Institute of Metrology, Quality and Technology. The concessionaires are not obliged to build metering devices for SIGFI13 and SIGFI30, since the owners of these systems pay the corresponding price for 13kWh or 30 kWh. It is obligatory for concessionaires to install metering devices for systems that supply minimum 30 kWh, so the consumers with such systems can pay for the amount of the electricity they use.

Concessionaires should also keep records of downtimes and are obliged to send ANEEL reports about the systems. These reports should specify the number of systems and their capacities, their primary sources, downtimes and components that caused disruption. According to the decree, DIC - Duração de Interrupção por Unidade Consumidora (Duration of Interruption per Consumer Unit) should not exceed 216 hours per month and 648 hours per year (ANEEL, 2004c). Considering that 216 hours is almost 9 days, it is possible to say that 9 days of non-operation in a month is very high. The annual allowance for the systems is average 2.25 days per month, which is more reasonable.
DCI is calculated with the formula below:

\[ DCI = \sum_{i=1}^{n} t(i) \]

DCI : Duration of Interruption per Consumer Unit expressed in hours for the period of observation;

I : Coefficient of interruption in the system for the period of observation, varying between 1 and n;

n : Number of interruptions in the system for the period of observation;

i : Duration of the interruption in the system for the period of observation, expressed in hours.

There were 5 concessionaires that implemented SIGFIs in their electrification plans: COELBA, AMPLA, AES SUL, ELECTROACRE and CEMIG. COELBA installed the highest number of systems, 5,000 (IEI, 2009). Almost all households were electrified with SIGFI13 systems, where the monthly capacity of the systems is 13 kWh.

A study by the International Energy Initiative (2009), IEI, showed that there are several advantages and disadvantages attributed to SIGFIs. The authors contacted 5 concessionaires, of whom 3 have implemented SIGFIs and 2 have not, to ask about their opinions about the resolution and the systems. Having expressed that the universalization of access to electricity would be incomplete without SIGFIs, concessionaires pointed out three major disadvantages: i) limited capacity of the systems; ii) public acceptance; iii) lack of incentives.

Limited capacity is a major drawback of SIGFIs. Commonly used SIGFI13 only allows beneficiaries to use lamps, small electronic devices, radios, fan and a small TV for 1 to 4 hours a day, depending on the devices and the length of use (IEI, 2009). It is not possible to use a fridge with the energy supplied from either SIGFI13 or SIGFI30. Considering that Brazil has warm climate, the capacity problem stands out as a major disadvantage attributed to these two systems. To have a fridge, TV and 3 illumination points, a household should have at least a SIGFI60 installed (IEI, 2009). According to a study by COELBA, 24% of the beneficiaries were dissatisfied with SIGFI13 systems, of which 77% gave the reason for dissatisfaction as the limited capacity of the system (Filho, 2007). It was reported that the obligation of providing households with alternative current causes a further decrease in the capacity of the systems, because 20% of the energy is lost during conversion (Filho, 2007).

Public acceptance is important in rural electrification. The capacity problems of the systems created a public opposition and made it harder for concessionaires to consider SIGFI as an important alternative to grid extension. It is assumed that the negative public view might have influenced the decisions about the method of attendance. It was also mentioned by the concessionaires that many people believed that they would never receive grid connection in the future if they accept SIGFI (IEI, 2009).

Filho (2007) argues that the introduction of the Resolution 238 of 28 November 2006 negatively affected the future use of SIGFIs in an indirect way. The resolution regulates the penalties that concessionaires receive in case of not meeting their universalization goals, and applies no fines to concessionaires if the cost of attendance is 3 times more than the contracted average cost of connection. The author expresses that this resolution might have caused a delay in the implementation of SIGFIs, given the fact that these systems are considered as an alternative against unfeasible grid extension.

Decentralized generation with renewable energies is relatively a new method of attendance to be widely implemented. Therefore, governmental initiatives are important to promote the use of such technologies. The resolution No. 083/2004 defined the criteria regarding the individual systems, but neither it introduced any mechanisms that would support the use of these systems, nor created a stimulus for national production of systems. The lack of incentives is a drawback of the resolution, because it puts concessionaires under pressure to fund systems and limits further employment. LPT started offering
generous subsidies for mini-grids with the introduction of a new manual in 12 February 2009, therefore it is possible to say that mini-grids are prioritized over individual systems. Considering the fact that individual systems are more beneficial for electrifying households that are located far from each other, it is clear that these two methods of attendance serve for different purposes and should be both incentivised for larger use.

4.2.2 Mini-Grids

Grid extension is the first option to be taken into account in rural electrification, but there are cases where this method of connection is either impossible or financially unfeasible. Mini-grids are becoming more and more popular in the world for the electrification of communities that are located far from the grid. Compared to individual systems, mini-grids offer higher capacities, so they can be the answer to capacity problems experienced with SIGFIs in cases where households are located close to each other. Mini-grids stand out as a long-lasting solution for communities that will not have the chance to be connected to the grid in the near to medium future.

The use of mini-grids with renewable technologies is a new approach in Brazil. Until the release of the Manual for Special Projects in Luz Para Todos, they were neglected within the program. With the release of the manual, 12 February 2009, mini-grids are considered as special projects and are supported with large incentives. 85% of the direct costs in projects that use mini-grid as the method of attendance is offered as subsidies, which was previously discussed in Section 2.3.6.

CEMIG has not used mini-grids as the method of attendance in the program. When asked by the International Energy Initiative, certain concessionaires expressed that they would not implement mini-grids as an attendance method and pointed out the fact that there was no regulatory framework as there is with SIGFI. The concessionaires pointed out the facts that there was no procedure to be followed for billing and limitation of energy flow per household, which are important for sustainable use (IEI, 2009).

Mini-grids are an important opportunity for communities that are located in Northern Brazil, especially the Amazon region, where there is no connection to the national grid. The chances that mini-grids would be used in Minas Gerais, if the regulatory framework was defined in the beginning of the program, is unknown. It is perceived by the author that the manual for special projects is mainly directed towards communities in the Amazon region. According to CEMIG, there are no plans for using such method of attendance for decentralized rural electrification in the future.

Luz Para Todos provides opportunities for different technologies to be used in the program. Certain factors are influential in the determination of the attendance method and technology. Even though there were different options, CEMIG selected individual PV systems as the sole alternative method of attendance for grid extension. Next chapter explains the factors that led to this selection by the company.

4.3 Renewable Energy Technologies in LPT in Minas Gerais

Rural Brazil shows different characteristics, even in the same state. Minas Gerais shows a great diversity when it comes to geographical conditions, distribution of income and communities. North and Northeast parts of the state are mountainous and house Quilombola and Indigenous communities, who prefer to live in isolated areas. Especially Quilombolas, traditionally live in very remote places, sometimes even on the rocks, as shown in Figure 16.

Isolated households and communities can only be provided with electricity by installing individual systems or decentralized grids. CEMIG was the sole concessionaire to use decentralized systems in LPT. The company has extensive knowledge about photovoltaic systems coming from years of experience. As previously mentioned, the company has taken part in several projects and programs that involved the use of photovoltaic systems for rural electrification. Besides, CEMIG has strong relations with the academia and takes part in joint research programs. One of the most important collaborations is between CEMIG and PUC (Pontifical Catholic University of Minas Gerais), where there is a laboratory with systems that
could imitate the sunlight. Recently, this system is being used to determine the most suitable paint to prevent overheating of cases that house elements of PV systems.

Even though there are other technologies that could be used for rural electrification, CEMIG has preferred to employ PV technology for individual systems. Few factors cause PV systems to be selected over other power generation systems. First, CEMIG has expertise in implementing photovoltaic systems. Second, the Decree No. 83/2004 obliges the company to build systems that supply electricity continuously, which is hard to reach with wind systems and biomass, because wind is not enough as a primary resource in these systems and continuity of biomass supply could not be ensured. Instead, solar radiation provides a more reliable source to generate electricity. Third, PV systems almost require no maintenance, except the change of batteries, which could be done every 2 or 3 years. Moreover, PV systems are associated to less safety risks than wind (Diniz, 2011b).

The company has wind power, biomass and small hydropower generation facilities, but never used these technologies for rural electrification purposes. Generation facilities with biomass require more maintenance activities, which is challenging to conduct in places that are very hard to reach, and needs continuous fuel supply. Small hydropower generation is only possible for cases, where construction equipment could reach the location. According to The Wind Atlas of Minas Gerais, only certain areas in the state, mainly in the North and West, show good wind potential (CEMIG, 2010a).

4.3.1 Planning and Implementation of PV Systems by CEMIG

CEMIG is one of the two concessionaires that officially implemented PV systems in a large scale in LPT, along with COELBA in Bahia state. In the beginning of the program, CEMIG determined a market potential of 7,000 PV systems, but only installed 2,500 (Diniz et al., 2011a). 2,100 of these systems are functioning now, with the rest being removed due to arrival of the grid or departure of the families from the original location (CEMIG, 2011e). After a flood in 2008, 250 systems on the islands of the Sao Francisco River were affected. The water reached the panels and the systems became unusable. Kyocera, the company that installed the systems, replaced the systems with new ones under insurance (CEMIG, 2011e).

CEMIG has reported using “Stand-Alone Photovoltaic Systems – A Handbook of Recommended Design Practices” by Sandia National Laboratories as the guide for dimensioning and installation of the photovoltaic systems (SANDIA, 1995). Households are evaluated to determine their energy demand, then are allocated a SIGFI that is considered sufficient to meet their needs. CEMIG inspects the household, already owned appliances and potential before installing the SIGFIs. According to CEMIG (2011e), there were approximately 1,900 SIGFI13, 500 SIGFI30 and 100 SIGFI80 systems installed. SIGFI13 systems were used for electrification of rural households, while SIGFI30 systems were used for farms and beneficiaries with economic activity. SIGFI80 systems were only used for schools and medical centers. Almost all of these systems are located in the North and Northeast of Minas Gerais. The reported costs of these systems including installation are presented in Table 19. The numbers after SIGFI indicate the energy availability of the systems and it is possible to see that there are clear economies of scale.

<table>
<thead>
<tr>
<th>SIGFIs and their costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
</tr>
<tr>
<td>SIGFI 13</td>
</tr>
<tr>
<td>SIGFI 30</td>
</tr>
<tr>
<td>SIGFI 80</td>
</tr>
</tbody>
</table>

Source: (CEMIG, 2011e)
Individual PV systems installed by CEMIG typically contain PV modules, batteries, charge controllers and inverters. For example, a SIGFI13 system has three 50 Wp PV modules, two batteries of 110Ah, one 10A charge controller and 1 inverter of 300 Watts.

In the following parts of this section, a thorough description of the processes followed by CEMIG for the implementation of PV systems in rural electrification is presented.

**Decision about the attendance method**

CEMIG has created fluxograms that questions all specific information to reach the most appropriate decision. The two categorized systems are Type 1 – SIGFI13 and Type 2 – a system with a 300 Wp generation unit (CEMIG, 2010b). \( C_{\text{grid}} \) is the cost of grid extension and \( C_{\text{PV}} \) is the cost of PV system. Since the economic activity in rural areas is mainly farming, all households are considered as rural producers of farming products to a certain extent. \( N_{\text{cpr}} \) stands for the number of consumers classified as Typical Rural Producer and \( N_{\text{cppr}} \) stands for the number of consumers classified as Small Rural Producer. A regular low-income household in rural area that meets its needs by farming would be considered as Small Rural Producer, while households that produce more than their needs would be considered as Typical Rural Producer. The reason behind this categorisation is to determine the energy need. More information about these users is presented below:

**Small Rural Producer:**

- 72% of the users in LPT are classified as small rural producers
- Monthly consumption up to 100 kWh
- Property ownership up to 50 ha
- Unless specified as Typical Rural Producer, all households are considered Small Rural Producer

**Typical Rural Producer:**

- 28% of the users in LPT are classified as typical rural producers
- Monthly consumption of 300 kWh
- Property ownership of 250 ha

The fluxograms take the possible load, the location and local electrification situation into account and lead to the most feasible solution. The fluxogram used for the electrification of communities mentioned is presented in Figure 18.
Figure 18: The fluxogram for choosing the attendance method for isolated communities

Source: (CEMIG, 2010b)
The fluxogram to electrify isolated consumers is shown in Figure 19.

**Figure 19: The fluxogram for choosing the attendance method for isolated consumers**

Source: (CEMIG, 2005)

**Determination of the load**

CEMIG needs to analyze the consumer profile to have an idea about the future income, payback times and supply of the demand before making investments. Households are classified according to their activities, as indicated by ANEEL (ANEEL, 2000). A household with no economic activity in the middle of a rural place would be considered as residential, while a household in a rural setting with economic activity would be classified as a rural consumer. Low-income users usually have a low demand of energy, classified as “Low-income residential consumer”, and are eligible for subsidies (ANEEL, 2000). According to this classification, final users can be provided with the most suitable SIGFI. SIGFI 13 systems are considered suitable by the specific decree for residential consumers with low income in isolated areas. 13 kWh is only
enough to have lighting and some basic electronic equipment, preventing beneficiaries from using refrigerators and such. The most used electrical appliances are reported to be small radios, televisions and fluorescent lamps (CEMIG, 2010b). Their average potential is shown in Table 19.

Table 19: Electric appliances and their average potentials

<table>
<thead>
<tr>
<th>Electric Appliance</th>
<th>Average Potential (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Radio</td>
<td>10</td>
</tr>
<tr>
<td>Coloured TV 18&quot;</td>
<td>70</td>
</tr>
<tr>
<td>Fluorescent Lamp</td>
<td>11</td>
</tr>
</tbody>
</table>

Source: (CEMIG, 2010b)

The use of these equipments during the day is represented in a typical load profile for low-income rural category as illustrated in Figure 20.

![Figure 20: Load profile of a typical low-income rural consumer](image)

Source: (CEMIG, 2010b)

**Guaranteed Monthly Energy Availability**

In order to calculate the guaranteed monthly energy availability from a SIGFI, solar irradiation should be known. CEMIG determined the solar irradiation in 853 municipalities of Minas Gerais based on the information available in the Solarimetric Atlas of Brazil. However, there are only 79 meteorological stations distributed in Minas Gerais. For the municipalities that lack information about solar irradiation, the company used a software called SURFER. SURFER applies a method named “Kriging method” to calculate solar radiation in places without measurement by the help of information about latitude, longitude, temperature, cloudiness and measured solar irradiation in the surrounding areas. The resulting solar irradiation map of Minas Gerais is shown in Figure 21.
According to this map, the Western and Northern parts have the highest irradiation, thus are more feasible to make investments. The reason that they are more feasible is that higher irradiation leads to smaller panels and reduces the costs of the systems while providing the same energy output. The simulation of the systems, including batteries, was reported to be made with the software PV-DesignPro version S. The software simulates the power generated according to local irradiation, charging of batteries, as well as making a financial analysis that calculates the costs, payback time etc. The information about every municipality is stored for future use.

**Definition of the required system**

Based on the typical load and guaranteed energy availability, CEMIG mapped its area of concession and determined the necessary panel peak power to be used in connection to SIGFI13. The map is illustrated in Figure 22. The map has 4 colours, red, orange, yellow and cream. Solar radiation (Q) between 4.97 and 5.26 kWh/m², where a 130 Wp photovoltaic panel would be sufficient to power a SIGFI13 is indicated with red; solar radiation between 4.96 and 4.60 kWh/m², where a 140 Wp photovoltaic panel would be used for the same system is indicated with orange; solar radiation between 4.25 and 4.59 kWh/m², where the used photovoltaic panel should be at least 150 Wp to be sufficient to provide energy to a SIGFI13 is indicated with yellow; finally, the areas that are not served by CEMIG are indicated with beige (CEMIG, 2010b). The map is largely dominated by the colour orange. The highest irradiation is experienced in a small area in the North, and the lowest radiation is measured in the South and in the East of the state. The only white area in the middle of the map indicates the capital Belo Horizonte.
A cooperation work between CEMIG and the Federal University of Viçosa examined the suitability of the systems to meet the requirements established by ANEEL. The aim was to test a SIGFI13, the minimum load to be covered, in several locations to see if it worked in desired standards. The test system was a typical SIGFI13, consisting of a 150 Wp PV panel (including three 50 Wp modules), 210 Ah batteries and a 300 W inverter. The system was not sufficient enough to meet the demand in all municipalities. Therefore, larger panels should be considered in order to have a verified SIGFI13 system in specific municipalities where the demand was not covered (Cabral, 2006). This means that some regions should have panels with peak power even higher than 150 Wp. Power output is dependent on the factors of local solar irradiation, cloudiness, seasons, temperature and others, so every region in the state might show different characteristics and need different configurations.

**Localization of the consumers**

Consumers can be categorised as isolated and/or remote depending on their location, but their surroundings also play a major role to determine the way to deliver electricity to them. Isolated settlements are usually located in areas that are hard to reach, such as islands and natural protection areas, where conventional grid extension is unfeasible. CEMIG has categorised isolated connections and specified the methods that can be followed to supply electricity services in each case:

- Communities located on islands: These communities can be electrified with conventional grid, hybrid systems with mini-grids and photovoltaic systems. Technical and financial feasibility determine the technology to be used. This means that the island could be either connected by overhead lines or decentralized systems.
- Communities located in natural protection areas: These communities can be electrified by photovoltaic systems and special grid extension. Again, technical and financial feasibility determine which technology to be used.
- Consumers located in natural protection areas: Consumers located in natural protection areas can only be electrified by photovoltaic systems, with the type of the SIGFI to be determined according to the load potential.

Source: (CEMIG, 2010b)
Cost evaluation

Costs are one of the major obstacles in rural electrification. Rural electrification can be 20 times more expensive than urban electrification (ANEEL, 2004b). The reasons behind this are low consumption, small number of connections and sparsely distributed consumers. It is necessary to conduct a cost analysis and compare with alternative options in order to verify the feasibility of renewable systems. In the case of CEMIG, the cost of grid extension, when technically possible, and the cost of using PV were compared to determine the type of technology to be used.

The average cost of connection by the grid per consumer ($C_{\text{grid}}$) is calculated by dividing the average project cost by the number of beneficiaries. $C_{\text{grid}}$ is influenced by the dispersion of households and the proximity of other communities that would accumulate higher consumption. The cost of the PV system, including the costs of the system, materials used and installation is indicated by $C_{\text{pv}}$. CEMIG used previous rural electrification projects as a reference to make a comparison between $C_{\text{grid}}$ and $C_{\text{pv}}$. About 6,207 projects conducted in LPT between 2004 and 2005 were taken as reference. Amongst them, projects that connected 15 to 25 consumers were selected. The reason to choose projects that included 15-25 consumers is a socio-economic study that were conducted within the program Luz Solar, which showed that communities usually consist of 20 consumers that are located around a school (CEMIG, 2010b). The details of every project vary significantly; it was reported that there was a project that electrified 400 households, while there were 2,976 projects that only electrified a single household (CEMIG, 2010b). Higher number of households to be electrified in projects greatly influences the average cost.

The costs are calculated according to a methodology suggested by the World Bank in 1997 about finding alternatives for development of the use of renewable energies in rural electrification in Brazil, especially involving states of Bahia, Ceará and Minas Gerais (CEMIG, 2010b).

The function to calculate the costs for supplying electricity to all consumers in a project (15-25 in this case) is expressed by

$$Y = 435.499 \, X + 2370.711$$

$Y$ is the price in Brazilian Reals per consumer and $X$ is the length of the grid to be extended in order to make the connection. The graph in Figure 23 represents the function. The calculated correlation according to the graph is 74.6% (CEMIG, 2010b). Unless there is an extraordinary situation that makes it impossible to extend the grid, it is the length that always determines the method of attendance.

![Figure 23: The relation between the length of extension and the cost of attendance](Source: CEMIG, 2010b)
For the chosen projects in LPT, a recalculation of the costs is done with the formula \( Y = 483.856 \times X + 2375.097 \). This recalculation has resulted with a correlation of 76.4\%, confirming the trustability of the previous study (CEMIG, 2010b). One should note that these calculations are based on the extension of the grid to electrify the community under normal conditions.

To sum up, the length sets the decision for the method of attendance, and according to CEMIG when grid extension costs twice as installation of PV system or more \((C_{grid} \geq 2C_{PV})\), PV systems become more feasible, thus are preferred (CEMIG, 2010b).

4.3.2 The Systems Used in LPT

CEMIG installed 2,500 PV systems in LPT. These systems included SIGFI13, SIGFI30 and SIGFI80. They were built for residential use, as well as to provide electricity to schools, churches and medical centers. Undoubtedly, this required systems with different sizes and they are categorized differently.

The company opened a tender for a turnkey agreement of the systems, meaning that the winner would have to provide the systems, install them, and hand them in operation. The Japanese company Kyocera won the tender and installed the systems. For easier maintenance, CEMIG decided to use one type of module and requested the use of three 50 Wp modules for all SIGFI13 systems.

System Configurations for Residential Electrification

Residential systems are designed to meet the basic needs of the users.

Residential System Type 1 – SIGFI13:

- Average capacity is 13 kWh/month
- Can accommodate up to 3 or 4 fluorescent lamps of 16/20 W for 4 hours a day.
- Radio, television and a satellite dish working for 5 hours a day
- Other loads could be a fan and a mixer if used carefully.
- Generation units with 150 Wp, controllers 10A, Inverters 300W and batteries 210 Ah

Residential System Type 2:

- Suitable for large households with average capacity of 36 kWh/month
- Can accommodate up to 6 to 8 fluorescent lamps of 16/20 W for 4 hours a day.
- Radio, television and a satellite dish working for 5 hours a day
- Other loads could also be used.
- Generation units with 300 Wp, controllers 30A, Inverters 600W and batteries 420 Ah

A SIGFI13 system in a rural residential setting is shown in Figure 24. The figure also shows the part below the panel, housing two batteries, an inverter and a controller.
System Configurations for Public Electrification

Systems for public electrification are larger than systems used for electrification of households. CEMIG installed 100 of these systems. Public electrification includes community centres, schools, churches, medical centers etc. Some of the systems could be very large, exceeding the SIGFI80. Detailed information about classification of these systems is presented below:

Type 1:
- Used for small buildings, such as churches and community centers
- Provides approximately 36 kWh/month
- Can accommodate up to 8 fluorescent lamps of 16 W.
- Radio and TV can be used.
- Consists of 300 Wp generation units, 30A controllers, 600W Inverters and 420 Ah batteries

Type 2:
- Used for schools with 1 classroom up to 36m², churches, health centers and others
- Provides approximately 48 kWh/month
- Can accommodate up to 13 fluorescent lamps of 16 W.
- Radio, TV, satellite dish and video player can be used.
- Consists of 400 Wp generation units, 30A controllers, 800W Inverters and 420 Ah batteries

Type 3:
- Schools, churches and other buildings with 1 room between 40-60 m²
- Provides approximately 67 kWh/month
- Can accommodate up to 13 fluorescent lamps of 32 W and 2 of 16 W
- Radio, TV, satellite dish and video player can be used.
- Consists of 560 Wp generation units, 30A controllers, 1,000W Inverters and 630 Ah batteries
Type 4:
- Schools with 2 classrooms of approximately 30 m² each
- Provides approximately 86 kWh/month
- Can accommodate up to 6 fluorescent lamps of 32 W and 16 of 16 W
- Radio, TV, satellite dish and video player can be used.
- Consists of 720 Wp generation units, 40A controllers, 1,800W Inverters and 1,050 Ah batteries

Type 5:
- Schools with 2 classrooms of approximately 40 m² each
- Provides approximately 100 kWh/month
- Can accommodate up to 8 fluorescent lamps of 32 W and 20 of 16 W
- Radio, TV, satellite dish and video player can be used.
- Consists of 900 Wp generation units, 40A controllers, 1,800W Inverters and 1,260 Ah batteries

Type 6:
- Schools with 4 classrooms of approximately 30 m² each
- Provides approximately 192 kWh/month
- Can accommodate up to 37 fluorescent lamps of 32 W and 30 of 16 W
- Radio, TV, satellite dish and video player can be used.
- Consists of 1,600 Wp generation units, 40A controllers, 2,500W Inverters and 1,600 Ah batteries

4.3.3 Used PV Technology

Japanese Kyocera provided all systems to CEMIG. For easier and effective maintenance, CEMIG chose all modules to be the same 50 Wp, KC 50T. 50T are polycrystalline modules that are used for rural electrification, water pumping, signalization systems, desalinization of water and many more applications. They have 16% efficiency and their dimensions are 639mmX652mmX54mm (Kyocera, 2007). Technical information about these systems is presented in Table 20.

Table 20: Specifications for 50T

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<thead>
<tr>
<th>Specifications for 50 T</th>
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<tbody>
<tr>
<td>Maximum potential</td>
<td>54 Watts</td>
</tr>
<tr>
<td>Tolerance</td>
<td>15%/ -5%</td>
</tr>
<tr>
<td>Voltage of maximum potential</td>
<td>17.4 V</td>
</tr>
<tr>
<td>Current of maximum potential</td>
<td>3.11 Amps</td>
</tr>
<tr>
<td>Voltage of short circuit</td>
<td>21.7 Volts</td>
</tr>
<tr>
<td>Current of short circuit</td>
<td>3.31 Amps</td>
</tr>
<tr>
<td>Height</td>
<td>639 mm</td>
</tr>
<tr>
<td>Length</td>
<td>652 mm</td>
</tr>
<tr>
<td>Depth</td>
<td>54 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>5.0 kg</td>
</tr>
<tr>
<td>Nominal operational temperature</td>
<td>47 °C</td>
</tr>
<tr>
<td>Coefficient of current temperature</td>
<td>(1.33x10^-3)A/°C</td>
</tr>
<tr>
<td>Coefficient of voltage temperature</td>
<td>(-8.21x10^-2)V/°C</td>
</tr>
</tbody>
</table>

Source: (Kyocera, 2007)
This chapter described the type of systems used for rural electrification in Minas Gerais. Unfortunately, the PV systems did not play the major role that people thought it would, due to the predominance of the grid, the lack of incentives, the PV systems being considered as a pre-electrification method and negative public view. Next chapter discusses possible explanations for this particular situation.
5 Discussion and Conclusions

5.1 Discussion

Local conditions determine the method of attendance in rural electrification. It is not surprising that LPT has been implemented differently in each state of Brazil, given the large area of the country. Different characteristics of the regions in Minas Gerais led to variations in the implementation of the program. It is possible to say that LPT was a success in the state with the number of connections realized, but the role of decentralized renewable energies in the program turned out to be very limited. Though limited, the installed systems should not be undervalued, because they provided electricity to citizens that live in areas where it was challenging to extend the grid. Inclusion of these citizens is important for creating opportunities for poverty reduction and human development with the access to electricity.

The Brazilian rural electrification programs had several changes during the last decades. In year 2002, the universalization law obliged concessionaires to provide all households in their areas of concession with electricity and this was ensured by the supervision of ANEEL. LPT was introduced shortly after the universalization law. Two important aspects to be mentioned about the program are (i) free connection for consumers, including the internal infrastructure for using electricity in households, and (ii) the reduced financial impact of universalization on the concessionaires. Within these conditions, there are number of reasons for the limited use of decentralized renewable energies and next paragraphs discuss these reasons.

The introduction of the universalization law required an obligatory inclusion of all households in the process of electrification. This created two difficulties for the concessionaires: a high number of connections in a short period and unfeasible investments to connect isolated and/or remote consumers. LPT made it obligatory for concessionaires to take electricity directly to households and install necessary equipment for the use of this technology. This made the process even more unfeasible for the concessionaires, causing them to have decisions based on financial conditions. In rural electrification, decentralized renewable energy technologies are usually considered as an alternative, when the extension of the grid is not technologically or financially feasible. These conditions occur when consumers and communities are located: far from the grid, in areas where it is not possible to extend the grid due to challenging conditions, near or in natural protection areas. CEMIG, the only concessionaire who used renewables for decentralized generation in LPT in Minas Gerais, has an area of concession that is shaped from various regions with different characteristics. Many households with decentralized systems are located in areas where it is only possible to reach either on horseback or helicopters, describing how challenging the conditions are. It was confirmed by the company that these technologies were solely used for cases mentioned above, emerging as a strong alternative for grid extension.

In Minas Gerais, PV was the only type of system used for decentralized power generation and such technology was only implemented by CEMIG. There are number of factors behind the decision of using PV systems. First, CEMIG has previous knowledge of PV systems and used them in rural electrification before, so it is more advantageous for the company to use this technology. Second, the wind potential of Minas Gerais is not sufficient for small wind power generation throughout the state, so PV was more favourable in terms of energy supply. Third, other technologies that required extensive construction work or frequent maintenance were discarded, due to difficulties in reaching remote consumers. Finally, CEMIG preferred a uniform system that would be easier to maintain, this might have also influenced the company to use solely PV systems from the same producer.

Even though the points mentioned created favourable conditions for decentralized generation with renewables, it is hard to say that they were largely used in LPT. Initially planned to consist of 7,000 systems, CEMIG only realized 2,500 connections in the program. The reason behind this can be the lack of incentives for the use of individual systems in LPT. Having started offering subsidies for mini-grids as late as 2009, the government has not created financial opportunities for individual systems. Even though it is understandable that mini-grids will play a crucial role in universalization of the Amazon Region, it is not...
clear why the same advantages were not offered for individual systems. While mini-grids are used for electrification of communities, individual systems are of high importance for the electrification of isolated households.

The company has created guidelines for the assessment of the right technology to be employed in rural electrification. Three points that affect the decisions are noteworthy: distance from the grid, natural conditions, and consumption potential of households to be connected. Even though the fluxograms did not consider the option of the extension of the grid for cases like islands and environmental protection areas, it is mentioned in the same document that it is also an option for these cases, creating an uncertainty. According to the same guidelines by the company, CEMIG considers PV systems to be applicable when the cost of extending the grid exceeds twice the cost of installing PV systems for the same connection. The potential of consumption also plays a major role in the determination of the method of attendance. The company tends to connect typical rural producers with grid extensions, hoping to improve production. Another aspect that is considered is the income of the consumers to be connected, again showing the importance of the potential consumption to the concessionaire. The arrival of electricity will improve the conditions of these families greatly, but a step further could be achieved by providing them with more available energy to create financial opportunities. Considering the fact that SIGFIs have limited power supply, this creates a vicious circle, pointing out the importance of the sizing of the systems and bringing out an important fact, the costs.

The sizing of the systems was an important aspect that limited the deployment of decentralized technologies with renewable technologies. There were 1,900 SIGFI13, 500 SIGFI30 and 100 SIGFI80 installed in Minas Gerais. 1900 SIGFI13 provide electricity to families considered as low-income consumers. SIGFI13 are powered with 150 Wp panels that provide minimum 13kWh of electricity per month. These systems are capable of meeting very low loads, meaning that almost only lighting, TV and radio could be used for short period of time during the day. Even though the beneficiaries received electricity for the first time in their lives, they were not fully satisfied due to the fact that the power supply was not efficient (Diniz, 2011b). Given the fact that Brazil is a warm country, it is not surprising to have a public opposition about SIGFIs that do not have enough capacity to power refrigerators.

Even though the Resolution No. 083/2004 by ANEEL requires SIGFIs to be autonomous for 2 days in case of no flow of energy. The defined interruption limits in the resolution are also high, allowing 9 non-operational days per month in certain cases. This might have contributed to the dissatisfaction of the consumers about the systems built. It is possible that the dissatisfaction of consumers might have created a political pressure on the company, limiting the use of decentralized renewable technologies to almost one third of the determined initial demand. Though not be feasible, providing users with larger systems could be useful to create a positive idea about such technologies, while contributing to human development. Customer dissatisfaction and limited power supply by decentralized technologies also led to a support towards grid extension by the Ministry of Mines and Energy and ELETROBRÁS, which might have influenced these authorities about the use of such technologies in the program.

The grid is well distributed in Minas Gerais and it is growing larger and larger with LPT over the years. The expansion of the grid is one of the facts that contributed to the lower number of connections to be made with PV systems in the program. Once unfeasible to connect financially, certain consumers and communities have become more feasible to be connected to the grid as the program advanced. This is mainly due to the fact that the expanding grid led to decreased length of extensions for the connections, creating favourable conditions for grid extension. It is also known that a number of PV systems were removed because of the arrival of the grid (CEMIG, 2011e). Therefore, it is possible that changes in conditions through the years in the program might have had impacts on the number of decentralized generation facilities with renewable resources to be built within the program.

Renewable energy systems require knowledge and experience. PRODEEM was a sad example that pointed out the importance of planning and maintenance associated to these systems. Having used such systems previously, CEMIG has extensive experience and knowledge about renewable energy systems,
especially PV. It is not known whether there were conditions that might have made these technologies feasible to use by other concessionaires in the state, even though none of these companies have worked with such systems before. So, even if the companies had projects that might have favoured renewable energy systems, they might not be able to consider it as an option, because they did not have any previous experience. So, one of the points that limit the use of renewables for decentralized generation is that they require expertise in order to be installed and maintained correctly to sustain a long and efficient life cycle.

Taking these points into account, it is possible to propose ideas separately for Minas Gerais and other areas. CEMIG will not build other PV systems for decentralized rural electrification (CEMIG, 2011e). This does not mean that new renewable energy technologies will no longer take part in power generation in the future, in contrary it is expected that grid connected systems will become more and more important. Costs related to these systems are decreasing with time and if they reach desired levels, it is possible that they will play a key role in rural electrification in the future with interconnected grid, increasing the share of these technologies.

For other areas either in Brazil, or worldwide, the case of Minas Gerais presents valuable information. It is important to create favourable conditions for the employment of these technologies. This could be achieved by incentivising the use of decentralized renewable energy technologies, while ensuring customer satisfaction by regulations. Customer satisfaction could be reached by using larger systems and providing continuous flow of energy. Beneficiaries should know that all systems have limitations, but it could be useful to reduce the impacts on daily lives of the users for creating a positive idea about these systems. Therefore, it is in the hands of the authorities and concessionaires to create conditions that would satisfy all stakeholders. Also, making these technologies accessible for all sizes of concessionaires with incentives and providing training activities could also be useful for the inclusion of such systems in various regions. These initiatives can make decentralized renewable systems more attractive and lead to possible replacement of grid extension in certain projects by concessionaires of any size.

According to the information gathered, the role of decentralized renewable energies in LPT in Minas Gerais was defined. This study showed that decentralized systems powered with renewable energy technologies are considered as a strong alternative in rural electrification. As in the example of Minas Gerais, certain factors might influence decision makers to abstain from such technologies. This is why most systems were located in areas that are hard to reach to conduct construction work. In other states of Brazil, or in the world, where challenging conditions are more common than Minas Gerais, a widespread use of decentralized power generation with renewable energy technologies could be needed. Therefore, the percentage of such systems in the whole program is only a result of the local conditions.
5.2 Conclusions

For 12 million Brazilians, it was hard to imagine a life with electricity before LPT. The program is one of the most important initiatives from the Brazilian government to fight inequalities and support the most disadvantaged in the country. LPT has provided citizens with a simple need of modern life and helped them to take a step towards human development. It had large positive impacts on the living conditions in rural Brazil. 91.2% of the beneficiaries said that their quality of life increased after the arrival of electricity (MME, 2009). This improvement was achieved through better educational and healthcare services, having better personal hygiene or simply by increased household income.

In order to reach universalized access to electricity in the country, Luz Para Todos considers three methods of attendance: i) grid extension; ii) individual systems; and iii) mini-grids. This study showed that there are various factors that play a major role in the determination of the method of attendance. The identified factors in the rural electrification process in Minas Gerais were the geographical difficulties, distance from the grid, distance between households, environmental laws and economic activity.

Geographical difficulties and distance from the grid are two important factors that favour decentralized renewable energy technologies over grid extension. Distance between households is also influential, either in selection between grid extension and decentralized renewable energy systems, or between individual systems and mini-grids. Environmental laws that forbid construction in protection areas favour decentralized renewable energy technologies. Concessionaires tend to connect households with significant potential of energy consumption by grid extension, expecting higher rates of return. This shows that economic activity also influences the determination of the method of attendance.

Even though LPT provided concessionaires with several technological options, CEMIG only used individual PV systems as an alternative method of attendance to grid extension. Previously planned to consist of 7,000 systems, there were only 2,500 installed. 2,500 systems represent 0.88% of the total number of connections in the program. Identified reasons for the low number of connections by decentralized renewable technologies are: i) lack of incentives that favoured grid extension (Incentives for mini-grids were introduced as late as 2009, but did not apply to individual systems); ii) absence of stimulus for the national production of the systems, which could have decreased the prices; iii) low power generation capacities of SIGFIs; iv) intermittent flow of energy; v) strong negative public view about SIGFIs; vi) decreased costs of connection by grid extension due to expansion of the grid over the years.

The reasons above show that regulatory framework and energy policy mechanisms are the most important determinants of the method of attendance in rural electrification. Thereby, it is important to introduce necessary regulatory framework on time to strengthen decentralized renewable energy technologies against grid extension. Energy policy mechanisms, such as incentives, play a major role in making these technologies more attractive for concessionaires. It is also important to take the fact into account that mini-grids and individual systems are used in different conditions, so they should be both incentivised to promote further use.

Decentralized renewable energy technologies emerge as a strong alternative when it is not technologically and/or financially feasible to make connections by grid extension. They are the sole technology for the electrification of households located in areas that are impossible to reach by grid extension, such as hilltops or islands. Furthermore, they have become a sound alternative to grid extension for cases that need long and expensive extensions.

This study showed that mutual satisfaction of stakeholders is important to promote wider use of decentralized renewable energy technologies. Therefore, further efforts are needed to create a positive view of such technologies, not only for the public, but also the concessionaires. This is possible by improving the legislative framework to promote larger systems that are supported by incentives. This approach would prevent financial burdens on the concessionaire and provide beneficiaries with systems that offer larger capacities.
LPT has succeeded in providing millions of people in Brazil with electricity, including almost 300,000 households only in Minas Gerais. The program is a great example to point out the importance of rural electrification in human development. Though realized to a limited extent, decentralized generation with renewable played an important role in the program and provided hundreds of households with electricity. Along with other programs created by the Brazilian government, LPT will be a milestone in Brazilian history for fighting inequalities and creating a socially unified and more developed country.

Given the information presented, it is clear that some initiatives should be taken in order to increase the share of decentralized power generation by new renewable energy systems in rural electrification programs. To enrich future research, following up on a number of opportunities is recommended by the author, these opportunities consider (i) a comparison of the LPT program in Minas Gerais and other states; (ii) an analysis of differences between decentralized systems used in Minas Gerais and other states, such as the Amazon and (iii) a comparison of the use of PV systems in the program by the two large concessionaires in two different states, CEMIG and COELBA.
References


CEMIG, 2011e. De Souza, Marcio, 2011. Discussion about the PV systems at Luz Para Todos. [Conversation] (Personal communication, 01 July 2011)


Diniz, A.S.A.C., 2011b. Discussion about the PV systems of CEMIG. [Conversation](Personal communication, 10.06.2011)


Filho, H.M.S. 2007. The example of LPT in Minas Gerais showed that decentralized power generation with renewable energy technologies was considered as an option when it was not economically and/or technologically feasible to extend the grid. It also pointed out that consumption potential, regional development, topography of the area to be electrified and the distribution of households to be connected were of high importance when determining the method of attendance, MSc. University of Salvador – UNIFACS

FURNAS, 2011. De Souza, I.C., 2011. Discussion about the Luz Para Todos Program at Energisa.[Conversation](Personal communication, 3 June 2011)


Annexes

Questions Prepared for the Interviews

Interview with Ivan C. Souza – FURNAS (03/06/2011, Belo Horizonte)

1. Why are there different concessionaires? How is the situation with concession agreements now?
2. Do you have a current map of concessions in Minas Gerais?
3. What is considered remote for Minas Gerais?
4. What are the main differences between PRODEEM and LPT?
5. How are the projects prioritized? Are there certain regions in Minas Gerais that need special attention?
6. Was there a study to evaluate HDIs after realized connections?
7. Are there decentralized isolated grids and individual systems used in the program?
8. What are the main problems encountered by the concessionaires in the program? When is the program expected to end?
9. How does ELETROBRÁS evaluate the systems? What are the reference costs?
10. How are the projects prioritized? Are there certain regions in Minas Gerais that need special attention?
11. How is an agreement in LPT? Is it possible to see a copy of agreements?
12. Why is there financial inspection?
13. What are the differences between regular and special projects?
14. Is ELETROBRÁS interested in ensuring local supply of fuels in biomass powered system?
15. How is the role of ELETROBRÁS in payments?
16. What are CRC funds?

Interview with Marcos Bragatto, Henrique T. Mafra, Oberdan Freitas, Jorge A.U. Valente, Daniel J.J. Bego - ANEEL (07/06/2011, Brasilia)

1. Do you think that LPT was different than other major rural electrification programs?
2. What is the exact role of ANEEL in the program?
3. When do you think that the program will be finished in Minas Gerais and Brazil?
4. What are the differences between Minas Gerais and other states in Brazil?
5. Do you think that the program was a success in Minas Gerais?
6. Are there any problems reported to ANEEL regarding the implementation of the program in Minas Gerais?
7. Why do you think that the role of renewable energies is limited?
8. How is the attitude of ANEEL towards the use of such energies in the program?
9. Do you think that the social tariff is important in universalization?
10. Considering the distribution of the consumers benefiting from the social tariff, how is their geographical distribution in Minas Gerais?
Interview with Reginaldo J.L. Oliveira, Dr. Aurélio Pavão de Farias – MME (08/06/2011, Brasilia)

1. Do you think that LPT was different than other major rural electrification programs?
2. What is the exact role of the Ministry in the program?
3. When do you think that the program will be finished in Minas Gerais and Brazil?
4. Has the Ministry experienced any difficulties with concessionaires throughout the program?
5. Why is the deadline of the program being postponed?
6. What are the differences between Minas Gerais and other states in Brazil?
7. Do you think that the program was a success in Minas Gerais?
8. What subjects are discussed in the committees that the Ministry takes part in?
9. What does the Ministry think about the employment of decentralized systems with renewable energies in the program?
10. Why do you think that the role of new renewable energy technologies was limited in LPT?
11. Did the Ministry encourage the use of such technologies in the program?
12. How do you see the future of rural electrification and renewable energies in Brazil?

Interview with Elmo Pechir and Nelson Bernis Abdo - CEMIG (10/06/2011, Belo Horizonte)

1. How is the current situation of the PV systems? What are the differences between LPT and PRODEEM?
2. Has LPT created better circumstances for larger implementation of renewables?
3. Why has not there been any biomass or biogas application?
4. How are LPT funds used for small hydropower plants?
5. How do you see the future of renewables in Minas Gerais and in Brazil?
6. Is it possible to say that LPT promoted renewables?
7. Where are the PV systems located?
8. What are the difficulties in regions of Minas Gerais?
9. What are the costs?
10. Why is the role of the renewables is limited?
11. What are the differences between Minas Gerais and other states in terms of renewable energies?
12. What is considered isolated in Minas Gerais?
13. What are the differences between PV and grid in terms of the quality of supply?
14. What happened in Sao Francisco Islands?
15. Why PV was the only technology to be used? Why have not you considered biogas or other technologies?
16. How many SIGFIs were installed in LPT at CEMIG? Can you provide numbers for each system?
17. Will there be more installation of PV systems in the program?
18. Why only 2500 out of 7000 systems were installed?
19. Could you explain the process of comparing the price of electrification with PV with other technologies?
20. Is it possible to reach guidelines for this calculation?
21. Is it possible to reach internally developed standards regarding PV systems at CEMIG?
22. Why only 150 Wp systems were used?
23. Why island settlements are provided with 300 Wp.
24. Did CEMIG have similar problems as other concessionaires in PRODEEM?
Interview with Dr. Sônia Diniz – PUC Minas Gerais (10/06/2011, Belo Horizonte)

1. Do you think that LPT was a successful rural electrification program?
2. What do you think about the role of renewable energies in rural electrification?
3. Do you think that renewable played an important role in LPT?
4. What were the technologies to be considered?
5. Why PV stands as the only solution in Minas Gerais?
6. Where are the systems located? How are the maintenance activities?
7. In which cases do you think decentralized generation could replace grid extension?
8. What do you think are the major obstacles against a larger use of such technologies in LPT?
9. How do you evaluate the demand for systems?
10. How is the process of planning of such systems?
11. Do you think that renewable energies will be employed for rural electrification in the future too?
12. How do you see the future of renewable energies in rural electrification?
13. What is the extent of the cooperation between PUC and CEMIG?
14. What are the main differences between the implementation of PRODEEM and LPT in terms of renewables?
15. What were the major problems that you experienced when you worked with such systems at CEMIG?
16. How do you see the future of renewable energies in Brazil?

Interview with Luciano S.L. Lima – Energisa Minas Gerais (20/06/2011, Cataguases)

1. What do you think about LPT?
2. How is the client profile of Energisa MG?
3. What are the major difficulties experienced in terms of electrification in the concession area of Energisa MG?
4. What is the cost of extending the grid?
5. How do you organize the program?
6. How do you consider the sustainability of the program?
7. Have you considered using renewable energies in your area of concession? If you have not, why?
8. Have you had consumers in your area of concession that would be more feasible to be connected by decentralized systems?
9. What do you think about renewable energies in LPT? What do you think is the major problem for the development of renewables in the program?
10. How do you see the future of these technologies in Brazil?
11. What is considered isolated for Energisa MG?
12. How are your costs related to the reference costs by Eletrobras?
13. Have you taken part at PRODEEM?
Interview with Marcio de Souza – CEMIG (01/07/2011, Belo Horizonte)

1. How is the situation with renewables in the program?
2. Why almost one third of the planned PV systems were installed?
3. Where are these systems installed?
4. What were the criteria for CEMIG to install these systems instead of the grid? What was the limit in terms of distance?
5. Why CEMIG has not considered other renewable technologies, such as small wind or biomass?
6. How many systems were installed? What are their specifications?
7. How do you determine SIGFI?
8. What are the materials and who are the providers?
9. Are there isolated grids?
10. What are the costs for installed systems?
11. How much of the systems were subsidized by the program?
12. How many systems are there now?
13. Why 250 systems were replaced in 2008?
14. Do you have a map showing the locations of the systems?
15. How do you see the future of renewable in rural electrification?
16. Do you have any hybrid systems in LPT? What do you think about their role in rural electrification?
17. What were the major problems that you encountered with PV systems?

Interview with Sérgio Mourthé – CEMIG (01/07/2011, Belo Horizonte)

1. Do you think that the social tariff plays a major role in universalization?
2. What are the technical criteria to benefit from the discounts?
3. How does CEMIG handle the social tariff? How is the process from the simple consumer to the top?
4. Is there a difference between rural and consumers with low income? Are there other advantages for rural consumers?
5. How is the distribution between rural and urban customers? Did the program change the percentage?
6. Has LPT created a large demand for the social tariff at CEMIG?
7. Has the last change in the law made increased or decreased the numbers?
8. How is the implementation of in individual systems and isolated grids?
9. How is the system for pre-paid systems?
10. What happens if there is a large family, or two families that live together?
11. What happens to the case of craftsman and family businesses in the rural area?
12. How is the situation in MG? Are there areas with high density of beneficiaries? If so, why do you think it is not homogenous?
13. How is the distribution between categories?