The Institutional dimension of rural electrification in the Brazilian Amazon.

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Abstract: The Brazilian government aims at providing complete electricity coverage for all citizens as a means to achieve development and reduce poverty. More than 2 million people living in the Amazon have benefited from the rural electrification program Luz Para Todos (LPT – Light for all), mainly through a grid-extension approach. Yet, there is general agreement on the need for an off-grid scheme in order to supply isolated areas. How can the actual institutional framework support the process of supplying electricity to these communities so that the trend of improving electricity access and quality of life continues? We aim at exploring the existing institutional dimension connected to LPT and identifying potential forms of organization for decentralized solutions in the Amazon region. Our analysis is based on current energy policy in Brazil, existing institutional framework, achievements of LPT and potentialities of the isolated areas in terms of resources. Our conclusions draw attention to potential approaches for the next step within LPT context. We argue that the off-grid approach must be based on the uniqueness of the isolated areas in the Amazon. We emphasize the relevance of renewable energy sources in the process of supplying electricity and securing inclusion of isolated areas in universal access.

Keywords: *Rural electrification, off-grid solutions, renewable energy*

In Brazil, significant governmental efforts have been put in place to enhance electricity access in rural areas since the 1990s. The last of these initiatives is called Luz para Todos (LPT – Light for all). It was launched in 2003 and has so far benefited about 11 million people, two of which live in the Amazon region. In general, grid-based systems have been used for the purpose of providing electricity to new users in Brazil, and the interconnected national grid supplies the majority of the population. Hydropower has been the most important energy source for electrification in the country. Despite its continental dimensions, Brazil has been successful in its program for electricity provision and has achieved about 88% of electricity access in rural areas. This makes Brazil the leader of universal electricity access in Latin America [1]. Traditionally, the availability of huge hydro resources and the search for economies of scale for power generation has promoted the development of a centralized electricity system. The fact that the government has allocated exclusive service territories for concessionaires has further promoted this centralized system [2]. Also the results obtained through the recent development of LPT are in line with the centralized approach, and mainly associated with grid extension for electricity provision. These results have not benefited yet an important group of people living in the Amazon region.

The Amazon region is assimilated hereby to the North region, as per defined in the macro-region division of Brazil. This has been usual practice in studies on the Brazilian Amazon. The Amazon region is the home of nearly 14 million people. and covers about 4 million km^2. This implies a population density of less than 4 inhabitants/km^2. The region is also characterized by a very sensitive eco-system. Extending the grid in this area is neither realistic because of the local topography and natural conditions, nor cost-effective because high investments would be required to benefit a few citizens with low income and consumption rates. Within this context, the target remaining in the Amazon is to provide electricity access to one million people who are still not connected [3]. Current challenges in terms of energy access are related to the exhaustion of the grid-extension model and mainly associated with

the provision of services in isolated areas where grid extension is not economically viable. Though a very small percentage of the Brazilian population, the dispersed inhabitants of the Amazon serve the important role of guaranteeing the sustainability of this rich and very sensitive eco-system. Poverty exposure can jeopardize their task. Thus reaching this population in their local environment is important. But here, a different scheme is required, based on decentralized systems and the exploration of renewable energy resources. The decentralized approach is characterized by the generation of power in a location closer to the final users, focusing essentially on meeting local energy needs. But, how to organize the electricity delivery institutionally, and guarantee its technical, economic and environmental sustainability?. There is a well-structured institutional framework which has proved effective for the purpose of improving energy access in Brazil. This institutional framework has successfully provided electricity access to 11 million people throughout the country in a short period of time [3]. However, these results have been achieved through grid extension. The government has recognized the need for developing an off-grid approach in order to provide electricity to the dispersed rural communities living in the Amazon region. Nevertheless, there is a gap between the institutional arrangements in place, which are focused on a model of centralized electricity provision, and the institutional capacity required to develop an off-grid, decentralized model of electrification. This gap needs to be overcome if universalization is to be achieved in the Amazon region [4].

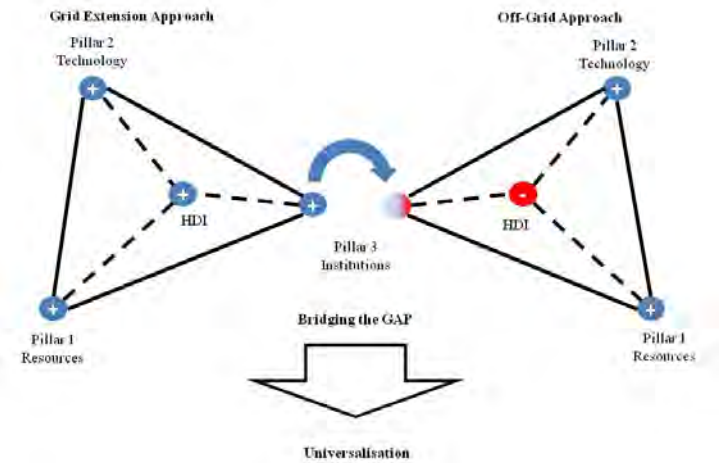

Fig. 1. Bridging the institutional gap for universalization in the Amazon region.

This paper explores the institutional characteristics of LPT and identifies improvements needed for the purpose of implementing decentralized solutions in the Amazon region. Our study has evolved around the analysis of three pillars of the electrification models applied based on grid-extension and off-grid approaches: (i) the resource availability; (ii) the technology applied and (iii) the institutional framework created to support the efforts (See Figure 1). How can the actual institutional framework support the process of supplying electricity to isolated communities so that the trend in improving electricity access and quality of life continues? The three pillars are crucial for the purpose of achieving human development. (see Figure 1). They are analyzed for both grid extension and off-grid approaches in the Amazon region. The isolated systems in the Amazon consider those electricity systems that are not connected to the national interconnected system. Though not interconnected, the majority of these systems have followed a centralized model that replicates, at a smaller scale, the national scheme. Electricity is provided through different approaches: (i) sub-grids that provide the main capital cities and nearby villages, also called Capital Isolated Systems and being developed through a grid-extension approach; (ii) mini-grids that provide electricity to small and remote villages and (iii) stand alone systems. The

extension of the sub-grids corresponds, for the purpose of this paper, to a grid-extension approach. On the other hand, the off-grid approach is related to minigrids and stand alone systems.

1. Pillar 1. The Amazon region: the potential of available resources

In face of the unfeasibility of extending the national interconnected grid, smaller but also centralized power plants were installed in order to provide electricity to the main cities in the Amazon. The grid extension approach has relied mainly on fossil resources and today about 60% of the installed power generation in the Amazon is based on diesel power plants. At a lower scale (less than 1 MW capacity per unit), suitable for off-grid applications, about 80% of the generated power is produced using diesel. The remaining 20% is produced using hydro resources [14]. Thus, while offering an opportunity to provide energy access without significantly impact the environment in the Amazon region, renewable sources have not been explored enough. In terms of hydro resources, the Amazon basin shows the largest potential for electricity generation in the whole country, corresponding to about 106 GW, that is, 42 % of the national potential [5]. But a nominal potential of about 1,7 GW has been quantified as appropriated for using small, off-grid hydro power plants [4]. According to the National Electricity Agency –ANEEL, 15 small hydropower plants are already installed. This implies a total installed capacity of just 12 MW in the region and illustrates the magnitude of the unexplored potential [14]. A number of opportunities connected to biomass resources have also been identified and actually implemented. For example, floating residual wood being carried by the rivers is already being collected in order to avoid danger for navigation. It might be used for power generation [15]. The possibility of using vegetable oils either in natura or processed as biodiesel has also been studied and applied at the level of pilot projects [6]. Though seven biomass-based power plants with an installed capacity of about 72 MW are in place in the region, just two of them have an installed capacity of less than 1 MW [7] A wide variety of native species are yet to be explored. Regarding solar radiation, the potential for every location is not well known yet due to the extension of the area and the difficulties in terms of accessibility. However, there is evidence of an average radiation of 5.5 kWh/m^2. This potential has low inter-seasonal variability, which makes it suitable for the purpose of implementing hybrid systems [10]. Finally, wind resource is found mainly in the coastal area and in Roraima, close to the border between Brazil and Venezuela. The average annual wind speed there is higher than 5m/s, suitable for the installation of small scale wind turbines with capacity at the order of 100kW [4].

To summarize, the grid extension and the off-grid approaches in the Amazon have relied on fossil fuels. Given the sensitiveness of the eco-system in the Amazon, widely available renewable energy sources offer an opportunity for fulfilling universalization goals that is still to be explored.

2. Pillar 2: technologies to provide electricity in the Amazon

The traditional grid-extension is not self-sustainable and does not promote sustainable development [10]. Some estimation exist that reveal the need for an additional installed capacity of between 456 MW and 1 GW for the purpose of attending isolated systems [11, 12]. Unlike the majority of the national inhabitants, most of the Amazon population is today supplied through the Isolated Systems. They are characterized by (i) the predominance of diesel-driven power plants; (ii) consumers that are highly dispersed; (iii) the inexistence of economies of scale and; (iv) significant difficulties of logistics for fuel supply in the region

Thermal and hydropower plants have been the main technologies used for both, the grid extension and the off-grid approach in the Amazon. The most significant difference between them is the scale. Since the grid-connected power plants supply the main cities and nearby villages, they usually have a capacity higher than 1 MW. On the other hand, the off-grid options, that is, mini-grids and stand alone systems, are related to power plants with a smaller capacity. The number of installed diesel-based power plants with a capacity inferior to 1 MW is more than ten times that of small scale hydro power plants (Figure 2). Regarding stand alone systems, diesel-based systems with capacities ranging from 10 to 66 kW are the most common. In most of the cases, communities are responsible for the installation and operation of these power plants. Some estimation exists that reveal the presence of about 3000 small-scale diesel driven power generators just in the Amazonas state. Unfortunately, these power plants are not registered in the official records [11, 12].

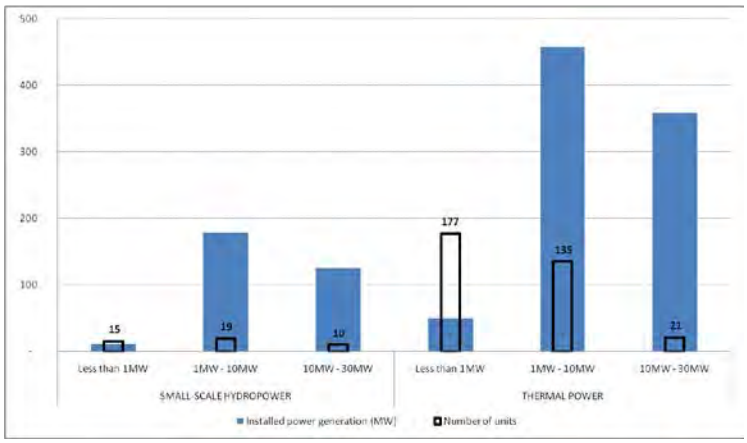

Fig. 2. Installed capacity and number of thermal and hydropower units in the Amazon (Less than 30 MW of installed capacity per unit). Source: [11]

Renewable technologies have in many cases proved cheaper and more appropriate than national grid extension when used in rural electrification [4, 13, 15, 21]. However, except for small hydro power plants, they are not used in the Amazon. The official records register just one photovoltaic system of 20 kW [14]. Biodiesel-based power generation has already shown its feasibility in stationary engines and gains importance in face of the vast biomass resources [6]. Photovoltaic technologies are suitable for lower demands than small hydro or biomass technologies. They have proved effective to provide services such as lighting and clean drinking water. On the other hand, wind energy technologies offer a good cost-competitive opportunity, in some cases with prices below those of PV, particularly effective for hybrid systems (PV-diesel) [10]. In any case, the simplicity, reliability, robustness, environmental aspects and low costs of operation and maintenance are key factors for the selection of the proper technology or mix of technologies (in the case of hybrid systems) to be implemented in a specific location.

3. Pillar 3: The existing institutional framework

LPT has obtained remarkable results in terms of poverty alleviation and human development, measured through the Human Development Index (HDI). These results have been achieved through a significant mobilization of political will and a precise definition of policies to promote full coverage [3] Resource availability, proven and mature technologies for electricity provision and a proper institutional framework have forged the success of LPT under a grid extension model. Isolated areas too have plenty of renewable energy sources that can be explored for electricity generation such as solar power and biomass. But the challenges

here are different to harness the resources and provide the technology at the local level. Can the achievements of the grid extension approach serve as the foundation for developing a decentralized approach?. If so, how can the institutional gap be covered so that the goal of universalization can be reached?.

LPT is a national program reflecting a national goal. It has created an institutional structure in which the roles of diverse players are specified at regional and local levels. Along this institutional line of action, responsibilities are attributed to organizations at the various levels, and activities are defined from planning to monitoring. At national level, a National Commission of Universalization (NCU) is in charge of defining the policies that lead to full coverage in the country and use electricity access as a driver for development. The multi-sectorial support of the policies, as per exemplified by the participation of as many as 13 ministries, together with the operationalization of the policies guaranteed by the regulator (The National Energy Agency -ANEEL), and the financial support of Brazil's major development bank are noteworthy. The National Management Committee (NMC) acts transversally, coordinating, supervising and monitoring the actions of the programme throughout the country. The coordination role is in the hands of the Ministry of Mines and Energy (MME). Eletrobras, a federal company controlled by the Brazilian government, is responsible for the Operational Secretariat and administers the financial resources provided by the corresponding sectorial funds At the regional level, the Territorial Committee accompanied by the State Management Committee (SMC) identifies and prioritizes electricity demand. The SMC receives and analyzes the demand requirements that are provided by the communities. At the local level, the concessionaires, together with the civil society act in the implementation of the program through specific projects. They work in close cooperation for the purpose of identifying actual energy needs. [8] .The monitoring activities have received particular attention and institutions at three levels have been designated to develop them. Eletrobras and ANEEL are in charge of watching over the statement of commitment signed between the Federal Government, states and implementing agents

Table 1 shows the main competences of the existing institutions involved in the development of LPT. Whilst this matrix does not show the entire spectrum of competences in every institution, it does give a good illustration of the main capabilities that serve the LPT at three different levels, national, regional and local, with the purpose of accomplishing 100% electricity coverage in the country. It also shows the preponderant role of the concessionaires at the local level, as they are the only ones directly involved in the implementation activities. This is the result of the regulation considering exclusive service territories for concessionaires. It also emphasizes a strong connection between existing technologies and implementing agents. In other words, concessionaires' expertise has grown based on the implementation of hydro and diesel-based power plants. In the search for universal access and based on the existing interconnected electricity system, Brazil has built a well structured rural electricity policy that is anchored at national, regional and local levels. However, the traditional and strongly grid-oriented approach has reached physical and economic limits in the Brazilian Amazon. It cannot be further developed. In terms of institutions, this approach has enhanced a concession model that is in its nature exclusive and creates difficulties for new stakeholders to come into the system. There is a need for a new approach focused on the demand-side and a decentralized approach, requiring different technologies and a different institutional framework. How will that be delivered?

In the process of providing universal access, the government has recognized the need for these new players and has taken action, creating some possibilities for them to be active. The

government has started the process to close the existing gap and the law has allowed the participation of new players within the existing concessions, where the concessionaires are not able to fulfill universalization targets. These possibilities are restricted where exclusivity contracts have been signed and further action from the government is limited by this fact. Yet, it is also possible for the concessionaires to establish commercial agreements with technology providers [2].

Table 1. Main competence of the institutions connected to LPT.

Level of action	Institutions	Competences							
		Policy	Regulation	Coordination	Integration	Prioritization	Operational Secretariat	Implement.	Monitoring
National	National Commission of Universalization NCU)	x							
	National Agency of Electricity (ANEEL)		x						
	Ministry of Mines and Energy			x					
	National Management Committee				x				x
	Eletrobras						X		x
Regional	Regional Coordinators			x		x			x
	State Management Committee								x
Local	Implementing Agents (concessionaires)							x	

Prepared by authors based on [8, 9]

4. Bridging the gap. Discussion and conclusions

The need for an off-grid approach has been generally recognized. Yet, the institutional framework for promoting the electricity access has not been modified or complemented for the purpose of appreciating the peculiarities of the isolated communities in the Amazon [9]. The Amazon is rich in renewable energy sources and various technologies can be applied for the purpose of providing electricity to isolated communities. These technologies have been identified by the government as critical for the purpose of reaching universalization [1, 18, 19].but the concessionaires do not have knowledge related to their installation and operation. This means that knowledge on a wide range of technologies could be better adjusted to the off-grid needs. The question is then if this implies the need for new agents for implementation, operation, maintenance and monitoring of the new off-grid systems. In this context, technology providers, community organizations and academic institutions, knowledgeable on specific renewable technologies, could add to the capacity that has been built by concessionaires in terms of management and operation of small scale thermal and hydropower plants. However, their action is limited by the existence of long-term contracts that give exclusivity to concessionaires.

Nevertheless, the concessionaires do have valuable information on the location and energy consumption trends in some of the isolated areas where they have been active and have worked in cooperation with local communities. This communication channels have been opened thanks to LPT. Local organizations, closer to the isolated communities, could then be responsible for some of the activities that today are in the hands of the concessionaires and that imply costly operation, maintenance and after-installation activities, due to the fact that concessionaires are located far away from the final users.

Thus, in order to reach universalization, the involvement of the concessionaires needs to be complemented with actions from other agents that can provide their expertise. An opportunity for existing institutions and new agents emerges for the purpose of providing electricity to the isolated areas. Actions from these new agents integrated with those from existing stakeholders could enhance the development of the required off-grid approach. Clear responsibilities for both private and public stakeholders are required to generate, distribute and supply electricity to rural inhabitants under a decentralized approach. Now, the need for a clear set of rules for new comers arises. It also does for concessionaires in connection to their new role. They could work at local level in cooperation with organizations with knowledge on the required new approaches and technologies. Technology providers, international entities and universities are examples of this type of organizations. The fact that communities are isolated and usually located far from the concessionaires raises the need for the participation of community organizations that are closer to the communities and can communicate with them easily. Such is the case of NGOs or cooperatives that have not been very active due to the existing centralized approach. Further, due to the size of the off-grid systems, management and operational skills requirements are less strict than those required to operate and manage centralized facilities. This could encourage the participation of local communities using local skills to operate the off-grid systems.

The design and implementation of the required institutional framework is complex due to the intervention of diverse public and private actors such as electricity companies, final users, funding, controlling and regulating institutions, national and local governments among others. Each of these agents has particular goals and creates the need for a clear set of rules to act. In this sense, actions from the government are crucial. There is no unique solution rather a combination of solutions that can be adopted. There are strengths that can support the process of universalization if properly complemented with the action of existing agents and new comers to be considered within the framework of LPT. Yet, clear rules are needed in order to build an enabling framework that brings together potential institutions and stakeholders when it comes to off-grid electrification of isolated villages. The governmental commitment exists and the recognition of the role that electricity access can play in addressing and achieving development goals is already in place. Now, the time has come for leading the establishment of a clear set of rules that facilitate action from the required agents and can support the development of a new and urgently needed approach.

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