

## LOGISTICS CHALLENGES OF DISTRIBUTION OF ELECTRIC ENERGY INSIDE THE BRAZILIAN AMAZON: THE CASE OF THE STATE OF AMAZONAS

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### Abstract

This study analyzes the challenges that the logistics of distribution of electric energy in the State of Amazonas, in the Brazilian Amazon. It used the conceptual bibliographic method, which consists of formulating guiding questions, collecting and organizing data in scientific and institutional databases to generate the sought answers. The results showed that a) the available energy matrix was sufficient to meet the beneficiaries of the light for all programs; b) the program promoted the increase in the human development index of the communities reached, whose service provided effectively served people with low family income; and c) the services reached the minimum quality standard required by the control bodies. The conclusion shows the need to improve the current supply, regardless of location, community, or city. This study's contribution to science is to present a critical analysis of a service provided in adverse scenarios, with unique characteristics, without exempting the minimum quality standards necessary for the final customer's satisfaction.

**Keywords:** Distribution logistics, Energy distribution, Quality of service, Light for all programs, Service logistics in the Amazon.

### Desafios logísticos da distribuição de energia elétrica no interior da Amazônia brasileira: o caso do estado do Amazonas

#### Resumo

Este estudo analisa os desafios que a logística de distribuição de energia elétrica enfrenta no Estado do Amazonas, na Amazônia Legal. Utilizou o método bibliográfico conceitual, que consiste em formular questões norteadoras, coletar e organizar dados em bases de dados científicas e institucionais para gerar as respostas buscadas. Os resultados mostraram que a) a matriz energética disponível foi suficiente para atender os beneficiários da luz para todos os programas; b) o programa promoveu o aumento do índice de desenvolvimento humano das comunidades atingidas, cujo serviço prestado atendia efetivamente pessoas de baixa renda familiar; ec) os serviços atingiram o padrão mínimo de qualidade exigido pelos órgãos de controle. A conclusão mostra a necessidade de melhorar a oferta atual, independentemente da localização, comunidade ou cidade. A contribuição deste estudo para a ciência é apresentar uma análise crítica de um serviço prestado em cenários adversos, com características únicas, sem isentar os padrões mínimos de qualidade necessários à satisfação do cliente final.

**Palavras-chave:** Logística de distribuição, Distribuição de energia, Qualidade de serviço, Programa luz para todos, Serviços logísticos na Amazônia.

### Desafíos logísticos de la distribución eléctrica en el interior de la Amazonía brasileña: el caso del estado de Amazonas.

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## Resumen

Este estudio analiza los desafíos que enfrenta la logística de distribución de energía eléctrica en el Estado de Amazonas, en la Amazonía brasileña. Se utilizó el método bibliográfico conceptual, que consiste en formular preguntas orientadoras, recolectar y organizar datos en bases de datos científicas e institucionales para generar las respuestas buscadas. Los resultados mostraron que a) la matriz energética disponible fue suficiente para atender a los beneficiarios de la luz para todos los programas; b) el programa promovió el aumento del índice de desarrollo humano de las comunidades alcanzadas, cuyo servicio prestado atendió efectivamente a personas de bajos ingresos familiares; y c) los servicios alcanzaron el estándar mínimo de calidad exigido por los órganos de control. La conclusión muestra la necesidad de mejorar el suministro actual, independientemente de la ubicación, comunidad o ciudad. El aporte de este estudio a la ciencia es presentar un análisis crítico de un servicio prestado en escenarios adversos, con características únicas, sin eximir los estándares mínimos de calidad necesarios para la satisfacción del cliente final.

**Palabras clave:** Logística de distribución, Distribución de energía, Calidad de servicio, Programa luz para todos, Servicios logísticos en la Amazonía.

## 1. INTRODUCTION

The service sector involves a wide variety of activities with diversity in products and processes which dictate market structures. Public utility services, essential in meeting the community's demands, include telecommunications, sanitation, water, transport, security, electricity, etc. The distribution of these utilities has an essential effect due to the distribution logistics. The purpose of distribution logistics is to enable the use of a particular good or service in the correct quantity, in the right place, and at the right time, all previously agreed upon and adjusted according to the end customer's needs and demands. With an intimate relationship between space and time, this quantity accuracy requires careful planning to guarantee the return of investments committed in line with customer satisfaction, making it possible to leverage new services, ensuring a lasting relationship. In the opposite direction, delays in providing services compromise this relationship and expose the product supplier to veiled negativity in the commercial environment. All of this becomes more complex and challenging in the Amazon region.

Due to its extension and characteristics in the Brazilian Amazon geography, the state of Amazonas presents exclusive peculiarities that are different from the normalities presented by the other states of the Federation (Ramos, Silva & Santana, 2019). Its dimension, allied to the barriers imposed by the green geography of the forest, shelter a diversity in flora and fauna in the equatorial climate, with large demographic voids and means of transport based on the rivers of the region, since the state has only 25 State paved roads, the so-called AM. The main ones are found around the Metropolitan Region of Manaus. This reality translates into very few paved roads that offer guarantees of slow and stable locomotion, coupled with a deficient availability of aerial locomotion. In addition to this peculiar reality, regulatory frameworks, laws, and other devices are added to protect and ensure the region's environmental preservation.

The State of Amazonas has 62 municipalities, of which only the capital Manaus and Parintins have a population above 100,000 inhabitants (IBGE, 2016). The remaining 60 municipalities are distributed in a mixed immensity of forests and rivers, composing shared geography with numerous groups and a small number of people, commonly called communities. These communities are isolated by natural and geographical conditions and are characterized by partial dependence on resources outside their borders. For this reason, they are closed in on themselves, as shown by Mocellim (2011). Among these resources is electricity. The challenge is not only to supply energy but to supply with a minimum standard of quality.

With these restrictions, the State of Amazonas' interior stands out when the service sector is highlighted. In this respect, the distribution of electricity assumes specific and different

characteristics from other states in Brazil. Its distribution is necessary to guarantee a fundamental right. According to Ribeiro and Santos (1994), the Federal Government must offer it to populations or communities, and the energy distribution must be entrusted to authorized concessionaires. Access to this service allows for greater social and digital inclusion, quality of life, and social well-being while allowing for an increase in rural production, in addition to domestic use, according to Ribeiro and Santos (1994) and Camargo, Ribeiro, and Guerra (2008). The unity of analysis of this research was the National Program for the Universalization of Access and Use of Electric Energy, better known as the Light for All Program. This program was instituted by Decree 4,873, of November 11, 2003 (Brazil, 2003), determined to provide a portion of the Brazilian rural area that is not yet served by this public service access to electricity until the year 2008.

The provision of public service, in essence, aims to serve the interests of the community, to individually meet the needs of the citizen through the provision of services offered by the state and its authorized agents, with the clear objective of benefiting everyone. Thus, the public administration is responsible for offering services that meet society's interests while preserving their rights.

The present study seeks to understand the extent to which the particularities of the State of Amazonas' interior expose the difficulties of electricity distribution logistics. For this reason, the overall objective was to analyze the challenges that distribution logistics face supplying the interior of the Brazilian Amazon with electricity, analyzing the reality of the state of Amazonas. It investigated the functioning of the electric power generating units in the State of Amazonas' interior and their differentials concerning the National Interconnected System. It evaluated the geographical barriers in the State of Amazonas that influenced the electricity distribution quality and verified the performance indicators of generating electric energy units under the macro logistics optics.

## 2. ENERGY SUPPLY IN THE BRAZILIAN AMAZON

Efficiency, within the scope of electricity distribution logistics, is entirely essential for companies' sustainability related to this service. Concessionaires and distributors are permanently subject to challenges and unforeseen circumstances as they explore a branch that does not depend exclusively on their professional staff's common knowledge and skills. They are on the margins of unforeseen climatic events, changes in public policies, changes in regulatory frameworks, inspections of regulatory agencies, and, in an entirely justifiable manner, subject to charges and complaints from users of its services. Meeting multiple demands requires innovative solutions through changing processes, diverse redesigns, and its professionals' constant requalification.

In the case of public service, it is essential to seek favorable conditions for developing its logistical structure that supports the distribution of energy, which includes the provision of a service for the delivery of an intangible product, which is electricity. The mobile assistance and service provision units are mandatory throughout the national territory. They aim to maximize a benefit continuously expected by all their consumers through energy logistics, as defined by the IBGE (2016).

Electrification in Brazil started at the end of the 19th century with the construction of small electric power plants designed to meet cities' initial demands exclusively. It shows a character of differentiation concerning rural areas where electrification services in the field would be in charge of the interested ones in acquiring it. Due to its high cost, electricity has become a sole factor in Brazilian society's history (Camargo et al., 2008). This exclusion is best observed in rural areas, as opposed to urban areas, due to the lack of electricity utilities, which justify the non-application of

resources due to their high amount due to the low demographic density coupled with the low level of income.

In this environment, it is necessary to incorporate public policies on the part of governments to meet the energy needs of the populations involved in which local development will only be encouraged by the existence of electricity, and its access must be offered and encouraged by government policies. Becoming a fundamental right of the population to allow greater social and digital inclusion, well-being and quality of life and promoting rural productivity, according to Ribeiro and Santos (1994) and Camargo et al. (2008).

The absence of electricity in rural areas contributes to the widening of regional and national inequalities, which aggravates agricultural production in its various processes that precede planting, during, and after harvest, without considering the minimum benefits to serve the well of families living in these areas. In this perspective, rural electrification becomes an essential strategic factor whose purpose is to minimize poverty, increase sustainable development, increase the country's human development index, providing access to health, education, communication, and well-being (Gómez & Silveira, 2010).

Emigration movements from the countryside to the city exaggeratedly increase the rate of population growth, which generates uncontrolled urban infrastructure, leading to the appearance of slums, violence, high unemployment rates that compromise the quality of life with various problems. In this context, it is essential to improve the rural population's quality of life to reduce this migratory movement to cities (Camargo et al., 2008).

On April 26, 2002, the Federal Government enacted Law 10.438, which provided for the expansion of the supply of emergency electricity, significant tariff recomposition, created the Incentive Program for Alternative Electric Energy sources, and created the Energy Development Account (CDE) among others (Brasil, 2002). CDE is a sectorial fund that aims to fund public policies in the Brazilian electric sector. Among these policies is the universalization of the electric energy service throughout the national territory to establish tariff discount concessions for services that include low rural income, irrigation services, public water, sewage and sanitation, energy generation and consumption from encouraged sources, and the user's guarantee of having access to the public service provided directly or indirectly by the state, through the tariff moderation device.

ANEEL Resolution No. 223, of April 29, 2003, standardized preparing universalization plans. On November 11, 2003, Law 10.762 limited the service to areas with voltage lower than 2.3 kV. It installed load to 50 Kv per consumer unit while determining the priority of service to municipalities with a household acceptance index lower than 85%. Finally, it established the legal conditions to allow financing of universalization plans with Union resources. Table 1 describes this reality.

**Table 1.** Consumer classes, consumption variations, and consumers in the capital and interior of Amazonas (2017 and 2018)

Consumer Classes	Consumers 2018		Consumers 2017		Consumers variation (%) 2018 - 2017		Variation in consumption (%) 2018 - 2017	
	Capital	Inland	Capital	Inland	Capital	Inland	Capital	Inland
	532,666	333,395	522,492	320,750	1,95	4,43	0,51	- 0,86

<b>Residential</b>	1,578	1,065	1,680	1,083	- 6,07	- 1,66	- 22,86	4,22
<b>Industrial</b>	48,043	28,541	48,043	28,170	0,65	1,32	0,53	4,09
<b>Commercial</b>	3,883	51,489	3,883	50,773	- 0,62	1,41	14,65	1,14
<b>Total</b>	586,460	415,090	576,098	400,776	1,80	3,57	2,26	0,76

Source: Eletrobrás (2018).

According to data from the Brazilian Institute of Geography and Statistics (IBGE, 2016), in 2000, there were two million rural households that were not served by any public electricity service. No Estado do Amazonas, os dados atuais contrastam com as singularidades do lugar. Aqui estão a imensidão e a desproporcionalidade do território frente ao baixo número de consumidores ativos, quando se utiliza o critério comparativo entre a Capital Manaus e o interior. Over the previous years, the Federal Government made use of several rural electrification programs, culminating in the National Program for Universal Access and Use of Electric Energy, known as the Light for All Program. It took into account the reality at the beginning of the 21st century, and the attempt to minimize old disparities in energy offers between the city and the countryside in a generic way.

## 2.1 The light for all program

This program was created through Decree No. 4,873, of November 11, 2003, intended to provide, by the year 2008, complete access, in electric energy, to that portion of the Brazilian rural population that had not yet reached this public service. In the proximity of the initial deadline established and, subsequently, to the deadlines determined, many families not served by electricity were identified. There were changes in the program with the publication of Decrees 6,442, of 25/04/2008 (Brasil, 2008); 7,324, of 05/10/2010 (Brazil, 2010); 7,520, of 07/08/2011 (Brazil, 2011a); 7,656, of 12/23/2011 (Brazil, 2011b); 8,387, of 12/30/2014 (Brazil, 2014); and 9,357 of 4/27/2018 (Brazil, 2014), which resulted in the extension of the program until 2022 and the updating of its objectives.

The "Light for All" program prioritized the locations with the greatest number of needs. It encompassed rural settlements, quilombola communities, indigenous communities, communities located in extractive reserves, and in areas of electricity generation or transmission projects.

The difficulties are notorious and expose a complex dimension in terms of scope when considering the territorial dimension of the entire State of Amazonas. This evidence leads to questions that are generally not considered when thinking about the other entities of the federation: how to avoid interrupting the supply of electricity at different points and in different locations in Amazonas, taking into account its exclusive geography? How to maintain the continuity of electricity supply, taking into account the quality criteria established by ANEEL? How to serve all cities with their respective communities that are generally remote and even isolated by dense forests and extensive rivers? How to keep the interruption rates DEC (Equivalent Interruption Duration per Consumer Unit) and FEC (Equivalent Interruption Frequency per Consumer Unit) within their tolerable limits stipulated by ANEEL?

In the face of so many questions, the quality of the service provided by Distribuidora de Energia Eletrica is constantly put to the test, not only in contractual terms but mainly to expose its

level of supply to society. This view is defined as continuity of supply, quality of customer service, and quality of the electric energy product (Vacaro, Martins & Menezes, 2011).

## 2.2 Beneficiaries of the light for all program

In the geographical space occupied by varied ethnic groups and traditional peoples, in processes resulting from colonization and historical miscegenations, the inhabitants of the interior of the State of Amazonas enjoy a unique and simplified lifestyle, with the constant transmission of their culture to the generations later (Fraxe, Witkoski & Miguez, 2009). Part of these groups resides near the channels of rivers and lakes throughout the Amazon region and are known as riverside dwellers. They constitute a portion of society that does not access the same goods and services as other members of traditional Brazilian society. Originating from miscegenations of the Indian, white and black, the riverside people build their customs and values, "the riverside people build their ways of life, on the land, in the forest, and the rivers, and thus forge customs, values, practices, knowledge and languages" (Oliveira, 2015, pp. 75).

Due to the difficult access to services offered by the public authorities, inhabitants or riverside dwellers from the interior of the State of Amazonas are considered beneficiaries of the National Program for Universal Access and Use of Electric Energy, according to Decree 7,520, of July 8, 2011 (Brasil, 2011a), people domiciled in concession and permission areas whose service results in a high tariff impact. The concession area contracts are those that define the territories by an act of public power and that aim at the exploitation of public electricity services. Through the Electricity Distribution Permission Agreement, priority is given to serving the consumer market as a whole, not excluding low-income populations and less densely populated areas.

The Citizenship Territories Program established actions aimed at social and economic inclusion. Its objective was to provide better living conditions for people living in the country's interior, whose locations had an average population density of fewer than 80 inhabitants per km<sup>2</sup> and an average municipal population of up to 50 thousand inhabitants. The State of Amazonas has a population density of 2.23 inhab./Km<sup>2</sup>, and the municipalities in the interior of the state have an average population of 11,942 inhabitants (IBGE, 2016). The "Brazil without misery" program aimed to protect the population in extreme poverty situations or with a per capita monthly family income of up to R \$ 89.00 (eighty reais, 2018 values) per family.

According to the Institute of Energy and Environment, the program light for all carried out between 2011 and 2018, 67,190 connections (IEMA, 2019). The program benefits 268,760 people, taking into account a calculation of the average of 4 people served on each call. On the other hand, updating the figures based on the 2010 census, and indexed by population growth rates and population by census sector, comes to 159,915 people. This number represents 3.9% of the population of the State of Amazonas still without access to electricity. This quantity reflects the actual interior panorama of the state.

The interior of the State of Amazonas is eminently rural. Due to the difficulties of internalizing urbanism's lifestyles, such as basic sanitation, electricity, services and public assistance, consumer goods, transforming small population agglomerations into communities with characteristics intrinsic to the ethnic group to which they belong. The small population settlements in communities with characteristics intrinsic to the ethnic group to which they belong shape the State of Amazonas' interior, through its peculiarities, identifying it as an eminently rural State, except for the capital Manaus. Rural occupations lead land workers to dedicate themselves exclusively to them, leading them to work outdoors, unlike most urban occupations, as described by Sorokin, Zimmerman, and Galpin (1981).

### 3. METHODOLOGY

This study used the conceptual bibliographic method exposed by Nascimento-e-Silva (2012; 2020a; 2020b; 2021), developed in four stages. The first was the formulation of the investigation's guiding questions, together with the elaboration of the field study protocol, following Silva et al. (2020). Then the data were collected in scientific databases and in institutional repositories of Brazilian organizations that deal with the supply and regulation of electricity. The third stage was the organizing of the data. Fourth, the answers were generated for each of the guiding questions formulated in the first stage. Then, the responses were systematically written concerning the recommendations of Nascimento-e-Silva (2020b; 2021).

The analysis units consisted of scientific studies found in the scientific databases that portrayed the supply of electricity in the Amazon region, specifically in the state of Amazonas, and institutional documents of the supplying companies and official regulatory bodies. The analysis level was constituted the breadth of the explanation generated by the investigation. The state of Amazonas, as a prototypical example of the problem in the Brazilian Amazon. The analysis perspective was synchronous since the explanation generated is relative only to the present reality and not its evolution over time.

#### 3.1 Guiding questions

Three guiding questions were elaborated to guide the empirical surveys, following the guidance of Gil (2008), Furasté (2008), and Marconi and Lakatos (2003). Each guiding question was transformed into the following specific objectives: a) to describe the energy matrix that performs the supply of energy in the interior of the state of Amazonas, b) to identify the individual quality indicators operated by the electricity supply company in the state and c) to identify the quality indicators provided by the government to evaluate the provision of electricity supply services.

#### 3.2 Population and sampling

The population of this research was made up of all scientific studies on the supply of electricity in the Amazon region undertaken between the years 2000 and 2020 and the official documents of the companies providing these services in the region and of Organs regulatory bodies. No sampling procedure was performed since the researchers aimed to obtain and analyze all available studies and official reports to which they had access to carry out a census of this material for analysis. These documents helped to understand the scientific knowledge available on the electricity sector in the Amazon region.

Virtual documents were obtained, especially the electricity distribution procedures (Aneel, 2012; 2008; MME, 2016; 2008; 2018c; 2018d), those related to the quality of services (Aneel, 2016; 2019) and the annual reports of the Brazilian Ministry of Mines and Energy (MME, 2018a; 2018b; 2018c; 2017). The analysis of these documents made it possible to understand the dynamics of the electric sector in Amazonas.

#### 3.3 Data collection strategy and instrument

Data were collected with the aid of an instrument called data mass (Bentes et al., 2020; Nascimento-e-Silva & Rego, 2020; Nascimento-e-Silva et al., 2020; Silva, Martins & Nascimento-e -

Silva, 2020). It consists of a spreadsheet where the collected data and their respective sources are recorded. The strategy consisted of typing in the search tool of the Google Scholar and Scielo databases the response pattern and requesting that the searcher present the results. All responses obtained were first criticized for seeing if they met the standard of responses and recorded in the data mass. Otherwise, they were discarded.

### 3.4 Analysis and interpretation strategy of the results

The data were first organized in tables, tables, and graphs to correctly view the answers sought. Then, data in the form of words and phrases, as in the case of indicators, were organized with the semantic analysis technique's help, grouping similar responses that belonged to the same semantic field. After this first organization, the content analysis technique was applied so that the possible meanings of the answers found were identified in the search for understanding how that reality happened and why it happened that way. The interpretations were compared with the result of the literature review so that they could be fully understood.

## 4. RESULTS AND DISCUSSION

Here are the findings of the study, grouped according to the guiding questions. Thus, firstly, the characteristics of the energy matrix in the interior of the Amazon will be pointed out, followed by quality indicators for individual and collective consumers, ending with the indicators pointed out by the public sector for the configuration of quality in the provision of these services. At the same time that the results are presented, interpretive discussions of each of them are also made.

### 4.1 Energy Matrix of the Interior of Amazonas

The communities in the State of Amazonas are dispersed among the interior municipalities and have limited access to essential services. In this sense, services in precarious situations arising from public policies such as education, housing, health, and electricity supply, are characterized by precariousness. This deficiency is a consequence of little investment. The capital's power generation is of hydrothermal origin, while that of cities in the interior is thermal power (Zuza, 2019).

The Brazilian electrical system comprises two distinct sectors, one for the National Interconnected System (SIN) and the other for the Isolated Systems. The SIN (as shown in figure 1) comprises installations and equipment from multiple owners, intended for the production and supply of electricity in different regions of Brazil, configuring a predominantly hydroelectric system followed by natural gas, biomass, solar, and wind, coal, nuclear and oil. The interconnection of the entire system allows the transfer of energy between the subsystems.

**Figure 1.** Map of the horizon transmission system



Source: ONS (2019).

Isolated Systems (SI) are not connected to the SIN for technical or economic reasons and cover 235 locations, most of them in the Northern Region. Each system has a minimum structure to meet the electricity generation destined for an isolated location, its location mainly covering the Northern Region of Brazil, as shown in figure 2.

**Figure 2 -** Isolated systems in Brazil with predominance in the North Region



Source: ANEEL (2008).

The geographic and logistical dimensions of the State of Amazonas make it unique amid a complex business-state operation for the administration and distribution of electricity to the municipalities in the interior of the state. Unlike the usual practice in the Brazilian territory, whose generation is of the hydro matrix, the interior of Amazonas is assisted by isolated generator groups, known as Isolated Systems, installed at the headquarters of the municipalities, whose primary input used is diesel oil. Although the region is characterized by an extensive system of several rivers and their tributaries, diesel-fueled thermoelectric plants predominate in the state's interior. Isolated systems are the viable alternative to electricity supply, becoming a model that differentiates the logistics of electricity distribution from that implemented in the rest of the national territory.

The Northern region of Brazil comprises the majority of Isolated Systems. Their number reaches 272 systems, resulting in a representation of less than 1% of the total electric energy produced in the country. The predominance of fuel oil (diesel) represents approximately 96% of consumption for all thermoelectric generation. Table 2 specifies the composition of electricity production in the North of Brazil.

**Table 2.** Composition of the electrical matrix in isolated systems

Type	Thermal generation			Hydraulic generation
	Natural gas	Fuel Oil (diesel)	Biomass	
Headquarters				Dams
<b>Total (%)</b>	1,9	95,8	1,4	0,9

Fonte: ONS (2019).

In Amazonas, Isolated Systems' predominance is justified by the territorial extension of 1,559,146,867 Km<sup>2</sup> with an estimated population of 4,144,597 (IBGE, 2016) peculiar geography with environmental, cultural, and social characteristics that distinguish it from other regions of the world parents. Some reasons are highlighted, among which the fact that the isolated systems correspond to more than 330 locations, most of them in the North region, characterizing the "interior systems" differently from the "capital systems" (Zuza, 2019). According to the author, the isolated systems corresponded to 2,287 MW in December 1999, being 1,744 MW of thermoelectric and 543 MW of hydroelectric.

In the interior of the State of Amazonas, the Electricity concessionaire is responsible for the operation and maintenance of the Isolated System, composed of 95 thermoelectric plants, responsible for serving the headquarters of 59 municipalities and 36 localities operated by 45 own generator groups together with 613 generator groups leased and another voltaic park consisting of 12 mini plants. Table 3 describes these different aspects.

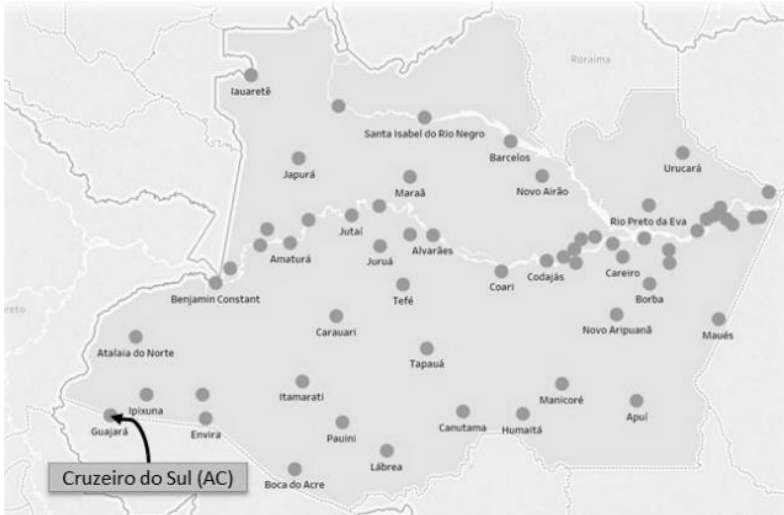
**Table 3.** Composition of isolated systems (SI) in the state of Amazonas in 2017

Thermoelectric Plants		Generator Sets			
Counties	59	Own	45	Diesel combustion	637
places	36	Leased	613	Natural gas combustion	21
<b>Total</b>	95	Total	658	Total	658

Fonte: Eletrobrás (2017).

In far greater numbers, thermoelectric plants dominate the production of electricity. This distribution complex was sufficient to supply electricity to 976,874 active consumer units in the State of Amazonas.

**Figure 3.** Isolated systems of the state of Amazonas



Source: ONS (2019).

Thermoelectric plants dominate the production of electricity and shape a complex distribution system. This production was sufficient to supply electricity to 976,874 active consumer units in the scope of 1,549,241 inhabitants, according to the typology presented in Table 4.

**Table 4.** Composition of isolated systems in the state of Amazonas (2017)

Thermoelectric Plants		Generator Sets			
Counties	59	Own	68	Diesel combustion	637
places	36	Leased	558	Natural gas combustion	21
Total	95	Total	626	Total	658

Source: Eletrobrás (2018).

The responsible distributor also has a voltaic park made up of 12 mini-plants to serve isolated communities in the interior. Furthermore, the Balbina plant, located in Presidente Figueiredo's municipality, the only hydroelectric plant in the State of Amazonas, has its energy produced and directly injected into the National Integrated System (SIN) as well as its accounting. The fuel that feeds the isolated villages' generators receives the subsidy from the Consumption Fuel - Isolated Account (TCU, 2009). This benefit has the purpose of making it possible for the tariff charged to the concessionaires to be similar to that charged in the other states of the country, maintaining parity of values between rural and urban, around R \$ 293.00 per MW / h (values 2019 CCEE). There are communities far from the local distribution networks, which manage their electricity consumption.

They are villages with a low-capacity generator, usually between 10KVA and 100 KVA, and a mini distribution network, whose absence of public administration implies self-management. The diesel oil used to power these generators are purchased from informal sellers or "marreteiros" who navigate the rivers buying and selling various goods at a high price. A painful and exhausting activity to be imposed on isolated communities as described by Lascio and Barreto (2009)

The diesel oil used as the thermoelectric plants' energy matrix in the Isolated Systems and the interconnected systems has its cost of acquisition subsidized through the Fuel Consumption Account (CCC). It is an account prorated by all Brazilian consumers of electricity, under the terms of Law No. 8,631 of March 4, 1993. Distributors are required to collect a proportionate proportion of the consumers served every month. The costs of distributors to support the CCC are passed on to all consumers through tariffs. The universalization of electrification in the State of Amazonas finds challenging geographical characteristics. Distances are great between cities, communities, and homes, making electrification procedures via conventional means impossible. In this sense, Reis Júnior (p. 23-24, 2015) highlights the initiative of the federal government in the enactment of Law 12,111, of December 9, 2009, determining that the operational expenses of maintenance of individual microsystems of energy generation should be borne by the fuel consumption account (CCC).

#### 4.2 Individual and collective service quality indicators

The social insertion provided by the light for all programs allowed an improvement in Amazonian communities' quality of life. "Electric energy allows changes in people's quality of life, acting as a lever for their economic development" (Dassie, 2016, pp. 2). In this sense, indicators reflect positively on access to primary conditions in which the exercise of citizenship is taken into account. However, disturbances caused by the interruption of the energy distribution caused by adversities caused by natural phenomena are beyond the concessionaire's control. They need to have minimized their impacts to the point of reestablishing the conditions before such eventualities. The universal use of electricity will consider achieving a minimum quality standard, regardless of its contingency character (Zuza, 2019).

In this context, the various communities and different locations in the State of Amazonas' interior have properties common to each other. These properties determine a culture combined with geographic and historical conditions set in the early days of its emergence. These communities have characteristics based on standard profiles:

- a) they are located along the banks of rivers and lakes, which are the riverside communities, located at great distances from the municipalities and without access by land;
- b) their access, even if only fluvial, depends on the navigability regimes of the rivers, either in times of ebb or flood;
- c) communities with little or no currency circulation, due to the absence of traditional trade, based mainly on activities in the primary and informal sectors;
- d) low population density located at great distances from the energy distribution networks, at the same time that they are formed by households concentrated around the church, school, community headquarters, and small commerce;
- e) provided with generator sets, they offer, on average, 3 to 6 hours per day of electricity supply, with priority for serving community wells for pumping water and running rural schools;

f) fuel, diesel oil is generally donated by city halls or other government agencies and is often paid for by the community itself; and

g) there is an already ingrained culture of practicality, functionality, and infallibility about diesel oil, in addition to the full knowledge, by the majority of users, about its use, operation, and maintenance involving electricity generators. Such a culture is an obstacle to popularization regarding the use of new technologies involving renewable matrices.

The expansion of the electric grid, intensified by the light for all program's arrival, meant a significant advance in terms of improvements for isolated populations, allowing them to enjoy a set of standard services in the cities. Another reality in these areas is the unexpected interruptions in the distribution of energy. As it is an area of dense forest, the connections are subject to wild animals' transit, which may eventually come into contact with the network causing short circuits and interruptions. The same will happen when trees or parts of them, either due to fatigue or rain or storms, touch the wiring, interrupting the electrical flow. In specific locations, the Light for All program's calls extend through difficult to access regions, giving repair teams considerable time in locating and repairing the transmission breakpoint.

Another sensitive point to expose the interruption of electric power is the constant thefts in causing an overload in the system, leaving it vulnerable to any fluctuation that may exceed the safety margin. Theft invariably maintains a close relationship with default, causing losses and sacrificing the entire community in question. For Araújo (2007), it is a conjuncture analysis involving the index of human development and integration into the society they belong to do. Table 5 shows the individual service quality indicators.

**Table 5.** Individual continuity indicators - the quality of service

Individual Indicators	Definition
DIC - Duration of Individual Interruption per Consumer Unit	It shows how long a consumer unit or connection point has been without power in a given time.
FIC - Frequency of individual interruption by consumer unit or connection point	It shows the number of times a Consumer Unit or Connection Point has been without power in a given time.
DMIC - Maximum duration of continuous interruption per consumer unit or connection point	It shows the maximum length of time that a Consumer Unit or Connection Point has been without electricity at a specific time. It limits the maximum interruption time to prevent the distributor from leaving the consumer a long time without electricity.

Source: ANEEL (2016).

Electricity interruptions for any reason expose quality as a negative characteristic of the service offered by concessionaires, regardless of the justifications presented and always highlighted in social, environmental, technical, and economic aspects, as established by Aoki et al. (2005, pp. 1): "It is defined, then, that an electricity supply service is of good quality when it guarantees, at viable costs, the safe and reliable functioning of equipment and processes, without affecting the environment and the well-being of people. ."

The need to establish quality standards fostered the creation of goals for the continuity of the electric energy concessionaires' service. ANEEL Resolution 024/2000 defines three individual indicators related to each of the consumer units and two collective indicators established for each group of consumers or any group of consumer units defined by the concessionaire and approved by ANEEL. In this sense, the quality standards of electricity supply are related to the interruption duration and frequency of interruption, which defines collective measurements through the indicators specified in table 6.

**Table 6.** Collective continuity indicators - the quality of service

Collective Indicators	Definition
DEC - Equivalent duration of interruption by Consumer units	It shows the average time that a consumer of a set of consumer units considered was without electricity in a specific time.
FEC- Equivalent frequency of interruption per consumer unit.	It shows the average number of interruptions that a consumer of a group considered has suffered in a given time.

Source: ANEEL (2016).

For regulatory purposes, interruptions will be considered and counted as long as they last 3 minutes or more (ANEEL Normative Resolution No. 482, April 17, 2012). The term "set" will be understood as any grouping of consumer units, global or partial, from the same distribution concession area, defined by the distributor and approved by ANEEL (Aneel, 2015).

### 4.3 Quality Indicators in the Public Electricity Service in Amazonas

The Brazilian government is molding itself to a new configuration. It clarifies its search for less intervention in the economy, emphasizing mechanisms embedded in regulatory frameworks, responsible for providing a healthy environment, allied to the economic and financial well-being of companies according to the demands of the consumer market. Public governance, which is exercised by the authority of a country through its traditions and institutions, is coupled with corporate governance debates and establishes rules oriented to good public management, whose objective is to satisfy the interests of the community, following the decree itself that regulates it: public governance - set of leadership, strategy and control mechanisms put in place to evaluate, direct and monitor management, to conduct public policies and provide services of interest to society. (Decree 9.203 / 2017). The World Bank conceptualizes governance as the "traditions and institutions by which a country's authority is exercised" This involves the process of selecting, monitoring, and replacing governments, the government's ability to formulate and implement sound policies, and respect for citizens (World Bank, 2020 ).

Governance statistics improve relations between the state and citizens through more responsible and transparent institutions. These statistics make it possible to identify groups affected by abnormalities within the governance systems themselves. They allow creating tools for directing public policies as aspired in the 2030 Agenda advocated by the United Nations Development Program.

**Table 7.** DEC / FEC indicators and limits in the interior of Amazonas compared to the national territory

Year	Interior of Amazonas				Brazil			
	DEC	FEC	ANEEL limit		DEC	FEC	ANEEL limit	
			DEC	FEC			DEC	FEC
2015	69,10	49,07	95,88	94,50	18,62	9,87	13,93	11,03
2016	74,53	50,62	92,03	91,73	15,82	8,88	13,31	10,33
2017	51,08	39,21	56,98	33,58	14,39	8,22	12,77	9,72
2018	43,81	24,66	72,36	84,65	12,88	7,11	12,72	9,52

Source: Eletrobrás (2017) e Aneel (2019).

The exam implemented here considers the DEC and FEC Collective Continuity indicators in the State of Amazonas to develop a precise and concise analysis with data made available in the public domain, as shown in Table 7. Collective due to the considerable territorial extension of the state. In comparison, ANEEL establishes limits to improve the calculations of regulatory parameters for quality indicators. The equivalent duration of the interruption in 2015 was significantly below the target established by ANEEL for the state's interior. An increase followed in 2016 and, in 2017, a decrease. It resulted in an arithmetic average of 64 hours and 54 minutes of interruption between 2015 and 2017. It was an interruption of more than two months in three years.

Despite this continued decline and below the Regulatory Agency's limits, the DEC quality indicator in the interior of Amazonas is still considerably distant from the limits stipulated for Brazil. The equivalent frequency of interruptions (FEC), accompanied by the DEC index, from the year 2015 to 2016 showed a tiny drop. In 2017, there was a drop of 11.41% concerning the previous year's index. The indices for 2015 and 2016 were well below the ANEEL limit for the State of Amazonas' interior. They decreased in 2017 but still above the limit stipulated for the region.

With a downward trend, the Amazon FEC index is very far from the National ANEEL Limit, with an average frequency in the three years 2015 to 2017 of 46.3, that is, in 3 years, there were 46.3 interruptions with at least 3 minutes of duration in the entire interior of the State of Amazonas. According to the Report of the Institute of Consumer Protection / Energy and Sustainability Program (IDEC, 2018). In 2018, the DEC and FEC indices for Amazonas' interior continued their downward trajectory in evidence of improvements in service provision standards to their customers.

The quality indicators reflect numbers and statistics analyzed and collected by some bodies and entities that are part of the hierarchy of Brazil's energy system. Its numbers express the quality standards obtained from the electricity distribution companies. When starting from the customer's view, individualizing him as someone who hires services or purchases goods for payment, one has a personified perspective in interests and perceptions related to what is expected from a public service provided by a concessionaire company. Based on this awareness, the client introjects a natural right simply by paying his taxes with the nickname "citizen." He expresses his conscience in an evaluative way, as all customer and citizen

In this sense, ABRADÉE, the Brazilian Association of Electricity Distributors, is a civil society under private law and non-profit. Among so many but with an analytical character, its purpose is to "carry out an annual national survey to find out the degree of customer satisfaction about the

quality of services provided by members." Among them is the Electricity Distributor in the State of Amazonas, the target of this investigation.

ABRADEE, as an evaluative institution, established the Consumer Approval Index (IAC). This index expresses the percentage of consumers who rated the grades of 7 ("good" or "excellent") with the quality of the services provided by the electricity distributor, disregarding those who did not know or refused to answer the exam (Abradee, 2019). These interviewees are asked another questionnaire with new questions to be analyzed and scored, such as continuity of supply, restoration of energy, quality of supply, prices, public lighting, problem-solving, customer information, and others. Considering the 2017–2019 triennium and directly and coherently, the research emphasizes that the distributor responsible for supplying electricity to the State of Amazonas was analyzed, taking into account exclusively the interior population, comprising the entire state the metropolitan region of Manaus.

## 5. CONCLUSION

The present study presented some of the main logistical challenges faced for the supply of electricity to isolated communities in the Amazon region, taking as a reference the case of the state of Amazonas. The distribution logistics implemented can be considered relevant. It acquired an exclusive character because it was associated with the constant maintenance in adverse conditions of what happens in the other states of the Brazilian territory.

It was found that the operation of the electricity generating units in the various isolated locations of Amazonas is eminently rural, with little evidence of cities or locations that contradict it as agricultural or rural, except for the capital Manaus. Rurality and the isolation attributes imposed by the geography of the forest and rivers fix an isolated and segregated electric energy supply from the national interconnection system's electrification network.

The geographical isolation barriers that influence and impact everyone living in the most diverse parts of the Amazon Forest were evaluated. The services offered by the electricity distributor occur in a sphere of totally adverse conditions. This adversity is attested by the great distances, the precariousness of fast transports, materials, spare parts most of the time in short supply, lack of fuel, or search in long journeys, generally carried out in small riverboats. Because of this reality, supplying communities in the interior of Amazonas with electricity is a challenging task. It is a challenge for both the federal government and the concessionaire of this public service, especially when considering the installation of generator sets, energy distribution to the various consumer units, supply, periodic maintenance, and unexpected maintenance.

The light for everyone program, with significant achievements, surpassed its predecessor, the light in the field program. Electrical exclusion has been minimized compared to past times. Today, 3.90% of the population of the state of Amazonas remains in the darkness of the second decade of the second millennium of the Christian age (IEMA, 2019). It expresses the absence of an essential public service that expresses relevant difficulties daily.

The macro logistics view indicates the need for continuous improvement to raise the quality of the services provided concerning the distribution and supply of electric energy made available to the State of Amazonas. Such indicators were analyzed and compared to the national average, indicating an unfavorable balance. It is clear and evident the great path to be taken to improve the quality of the service. For this reason, studies are recommended to find ways to reduce the disparity in the minimum standards of services provided so that the discrepancy concerning customers in other regions is not so significant. It is also recommended to carry out studies to measure customers'

satisfaction in these isolated communities with the quality of the energy they receive and the service that the company provides them.

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