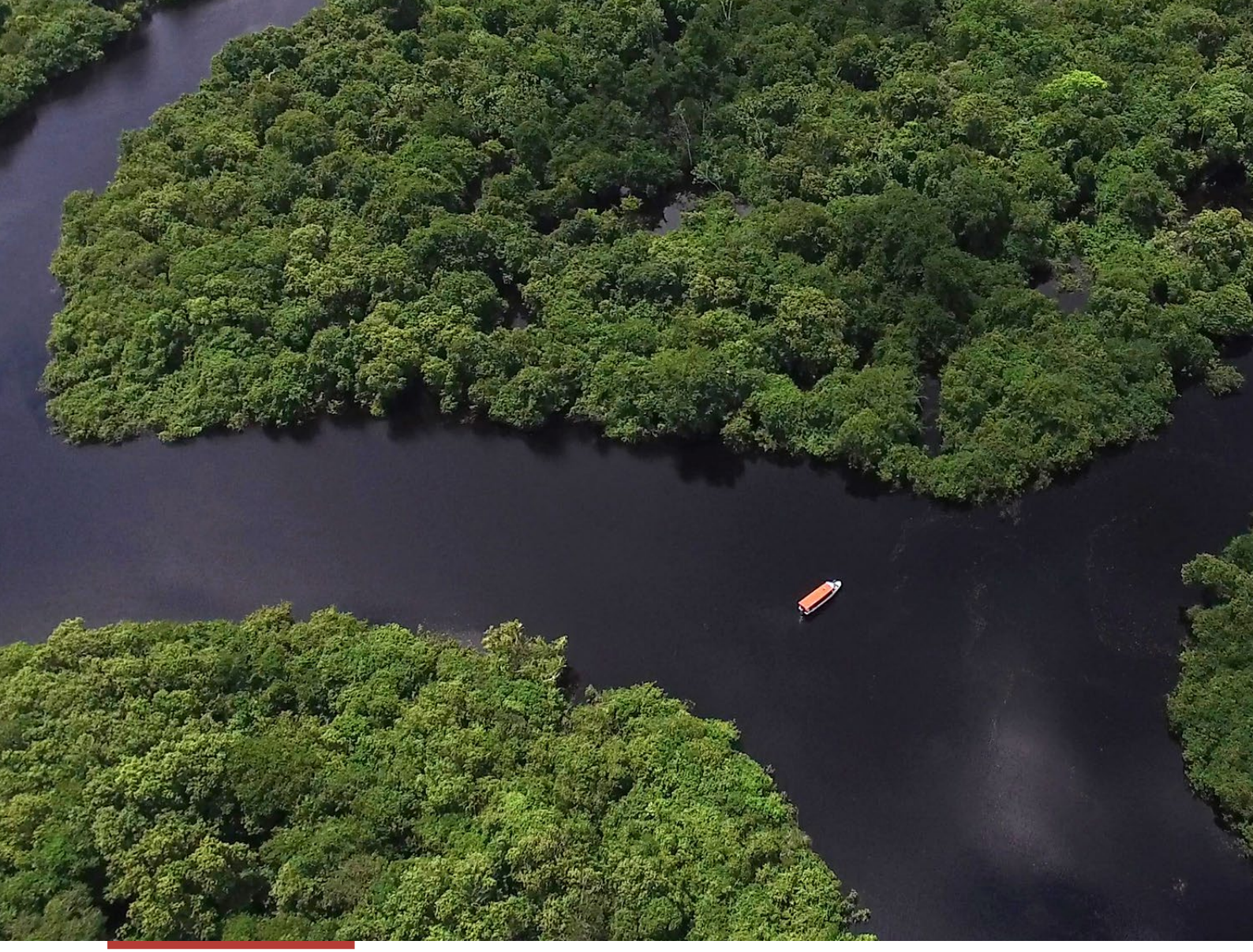


Rivers of Diesel in the Amazon: Why Does the Region with Brazil's Biggest Hydroelectric Plants Still Rely on Expensive, Dirty Fuel?

August 2022

CLIMATE POLICY INITIATIVE

PUC RIO

AUTHORS

Amanda Schutze
Head of Policy Evaluation, Energy, CPI/PUC-Rio
amanda.schutze@cpiglobal.org

Luiz Bines
Analyst, Energy, CPI/PUC-Rio

Juliano Assunção
Executive Director, CPI/PUC-Rio

ABOUT CPI

Climate Policy Initiative (CPI) is an analysis and advisory organization with deep expertise in finance and policy. Our mission is to help governments, businesses, and financial institutions drive economic growth while addressing climate change. Our vision is to build a sustainable, resilient, and inclusive global economy.

ACKNOWLEDGMENTS

This work was funded by the Institute for Climate and Society (iCS).

We are grateful for the excellent research assistance of Julia Martins. We would like to thank Rhayana Holz, Natalie Hoover El Rashidy, and Giovanna Miranda for their careful revision and copy editing, Meyrele Nascimento for formatting the text, and Nina Oswald Vieira for creating the figures.

We would also like to thank the following specialists for their participation in the qualitative research: Alexandre Henklain of the Fórum de Energias Renováveis de Roraima, Alessandra Mathias of the WWF, Donato da Silva Filho of Volt Robotics, Marcio Szechtman, Rafael David, Ricardo de Oliveira, and Carlos Eduardo Lopes of Eletrobras and Lucas Matheus of eAmazonia. Their shared knowledge was key to understanding the topic. Finally, we would like to thank Amanda Ohara from the Institute for Climate and Society for revising the content.

This publication does not necessarily represent the views of our financial supporters or partners.

KEYWORDS
Electricity; energy; Legal Amazon; isolated systems; people without access to electricity

SUGGESTED CITATION
Schutze, Amanda, Luiz Bines, and Juliano Assunção. *Diesel Rivers in the Legal Amazon: Why Does Brazil's Region with the Biggest Hydroelectric Plants Still Rely on Expensive, Dirty Fuel?* Rio de Janeiro: Climate Policy Initiative, 2022.

CONTACT
contato.brasil@cpiglobal.org

LIST OF FIGURES, TABLES AND BOXES

CONTENTS

EXECUTIVE SUMMARY

Brazil has earned international recognition for its largely renewable electricity mix. Renewables account for 82% of the electricity generated in Brazil, while the global average is just 27% (IEA 2020). This number reflects the existence of large hydroelectric power plants in the country, the biggest of which are located in the Amazon.[1] The states of the Legal Amazon were responsible for over 26% of the electricity generated nationally in 2020 but consumed just 8% of the total generated (EPE 2021).[2]

Yet over 14% of the population of the Legal Amazon lacks access to the electricity generated on the National Interconnected System (*Sistema Interligado Nacional* - SIN, hereafter interconnected system). This system produces and transmits electricity and connects power plants to consumers across the country. **So, on the one hand, the Amazon is a major electricity producer for the rest of the country, but on the other hand, a portion of its own population remains disconnected.**

This means that around three million people in the region must get their electricity from local plants that are not connected to the interconnected system, most of which are thermal plants powered by diesel fuel on what are known as isolated systems (EPE 2022). These vary widely and can be found in urban centers as well as very remote areas – places with different population sizes and energy demands. In addition, nearly one million people lack full access to electricity services, living with just a few hours of electricity per day from diesel or gasoline generators (IEMA 2020).

Diesel fuel is transported to power plants or for use in generators via waterways and roads, which presents logistical challenges.

Although the interconnected system reaches the Legal Amazon to connect the hydropower plants, they fail to connect several locations, primarily due to difficulties accessing these areas. The existence of small, scattered, and remote communities, along with environmental, logistical, and economic issues, makes it difficult to connect many of these places. **There is thus a contrast between the interconnected Brazil that runs on renewable energy and the isolated Brazil that runs on fossil fuels.**

It is more expensive to generate electricity in the isolated systems than in the interconnected system, because the isolated systems use diesel fuel and do not have the same economy of scale. The difference in cost between generating thermal power on the isolated systems and the same amount of electricity on the interconnected system is absorbed by consumers on their electricity bills. In 2022, the estimated value of the Fuel Consumption Fund (*Conta de Consumo de Combustíveis* - CCC) is over R$ 10 billion (EPE 2022), which amounts to a per capita subsidy of more than R$ 3,000 per consumer of isolated systems. **Energy transition in the Amazon is good for the environment and it will also mean lower electricity bills for all Brazilians.**

1 Four of Brazil's most powerful hydroelectric plants are located in the Amazon: Belo Monte, Tucuruí, Jirau and Santo António.
2 The Legal Amazon is a division of Brazilian territory comprising the entire states of Acre, Amazonas, Amapá, Mato Grosso, Pará, Rondônia, Roraima, Tocantins, and part of the state of Maranhão.

Solutions to the region's electricity issues cannot be analyzed separately from its development issues. **On average, the municipalities with isolated systems perform worse on a variety of socioeconomic indicators than municipalities in the** interconnected system**, compared to both the regional average and the averages of their respective states.**

The inequality in electricity service could be a symptom as much as a cause of the various socioeconomic problems affecting the Brazilians who live in these areas. A population without access to energy does not have its basic needs met, and this creates challenging conditions for health, education, communication, territorial defense, and production.

It is important to understand the existence of these two Brazils and, above all, to offer recommendations to bridge the gaps, both for the populations that are not connected to the interconnected system and for the country's environmental and energy outlook.

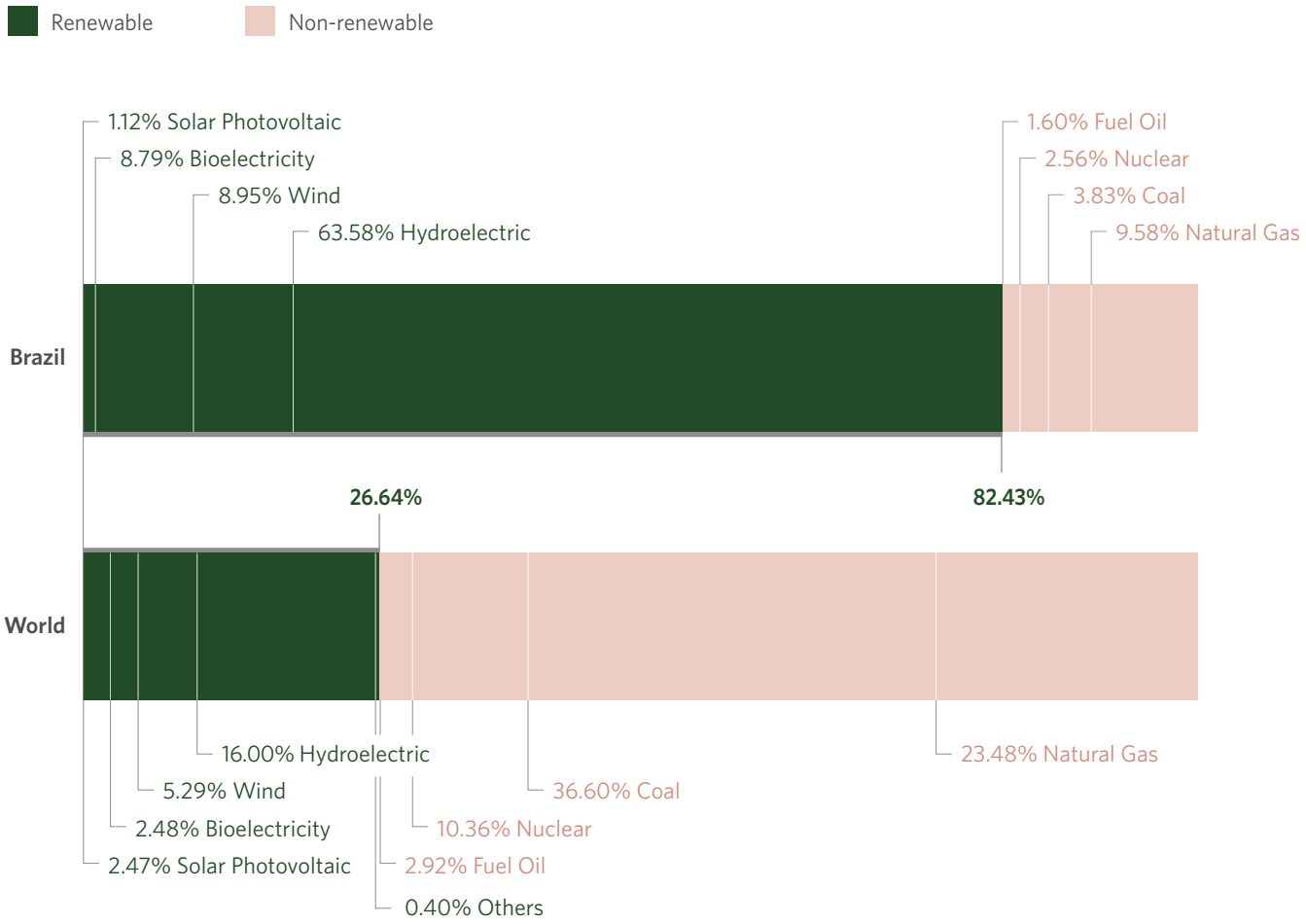
RECOMMENDATIONS

- Create favorable conditions for renewable supply initiatives to compete in the bidding for service concessions in isolated systems by modifying auction rules.
- Promote service for people without access to electricity by creating incentives for decentralized solar power.
- Improve the More Light for the Amazon Program (*O Programa Mais Luz para a Amazônia* - MLA) by creating clear goals and prioritization criteria and by incorporating effective oversight and local community involvement.

COMPARING ELECTRICITY IN BRAZIL AND IN THE AMAZON

Brazil's electricity mix is highly renewable, with 82% generated by hydroelectric, solar, wind, and other renewable sources. This is much higher than the global average of 27% (IEA 2020). Figure 1 shows the use of renewable and non-renewable electricity sources for Brazil and the world in 2019.

Figure 1. Comparing the Global and National Power Mix, 2019



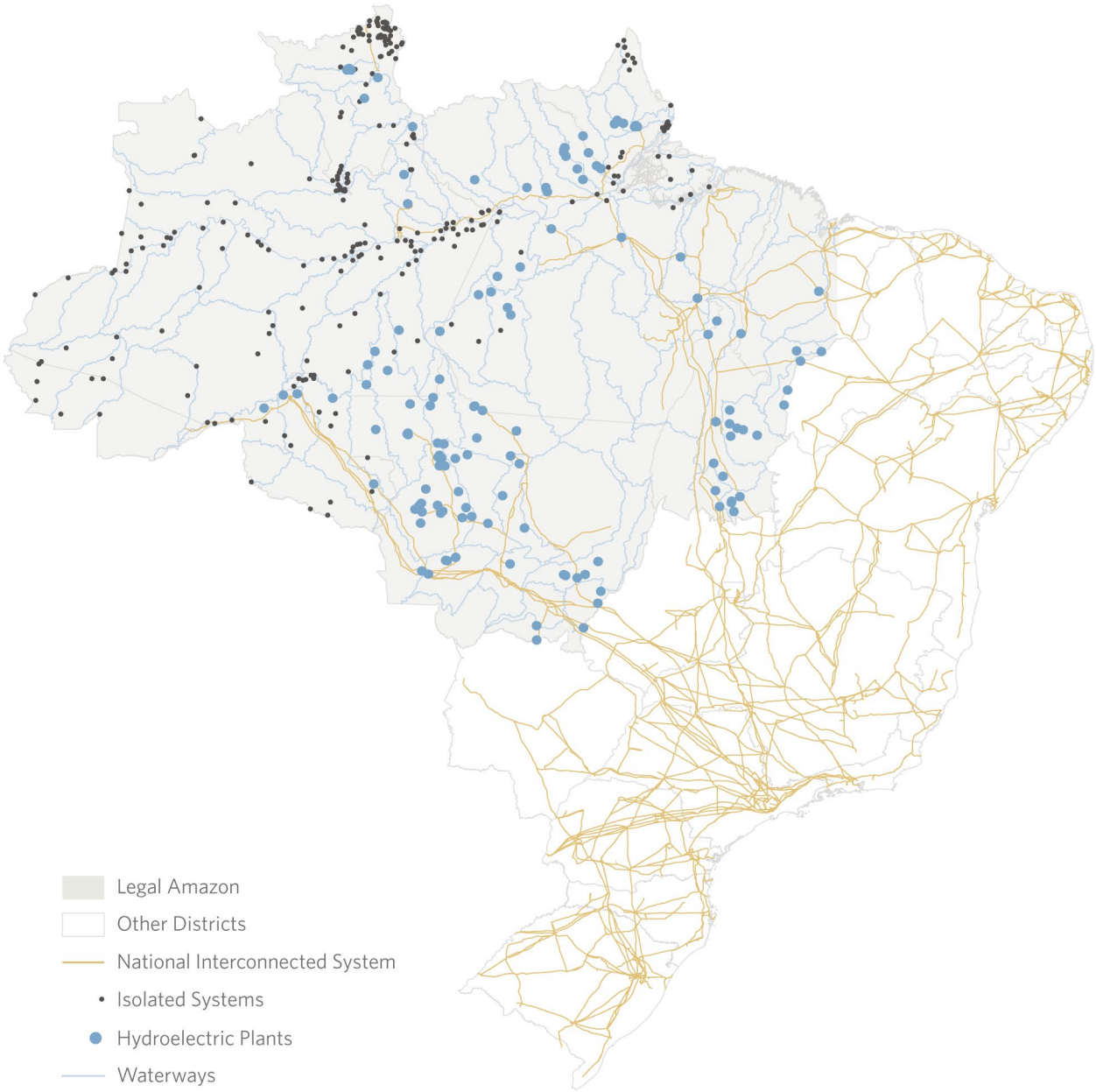
Source: *CPI/PUC-Rio, based on data from the IEA (2020), 2022*

In addition to its high rate of renewable generation, Brazil is able to distribute that energy throughout its regions via its interconnected system, a major network of installations and equipment that guarantees the supply of electrical power across the country. The transmission lines of the interconnected system connect power plants in every region, bringing the energy produced to consumers all over the country.

This system means that residents of a given region are less exposed to climatic conditions – such as the hydrologic regimes of river basins – or the operational conditions of their local plants since they have access to energy generated in other locations.

But the Legal Amazon – especially the states of the North Region of Brazil – have a different outlook than the rest of the country.[3] Around three million people in the region get their electricity from local plants that are not connected to the interconnected system, most of which are thermal plants powered by diesel fuel on what are known as isolated systems (EPE 2022). In addition, nearly one million people lack full access to electricity services, living with just a few hours of electricity per day from diesel or gasoline generators (IEMA 2020).

Figure 2. Map of Transmission Lines of the Interconnected System, Isolated Systems, and Hydroelectric Plants in the Legal Amazon



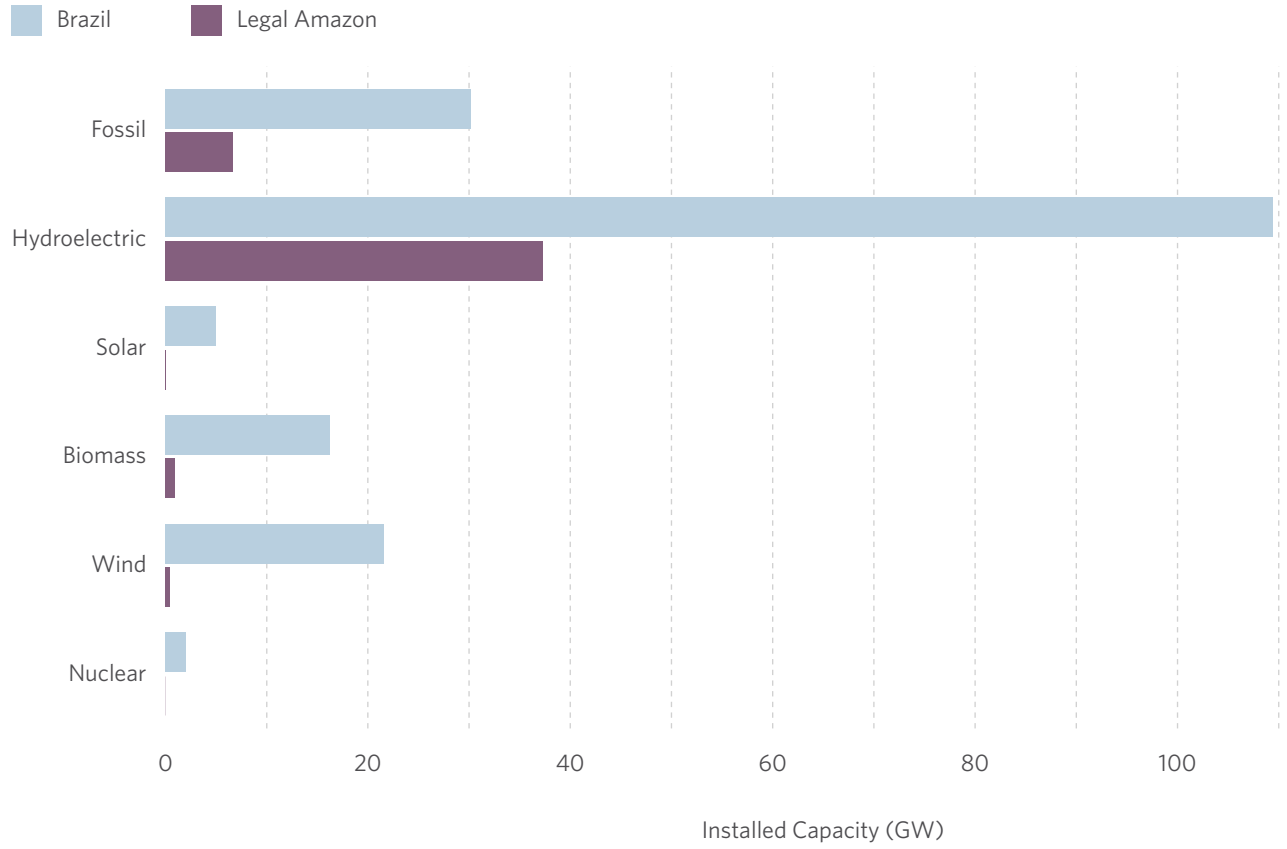
Source: *CPI/PUC-Rio, based on data from the National Electricity System Operator (Operador Nacional do Sistema Elétrico-ONS) and the EPE, 2022*

3 The Brazilian North Region and the Legal Amazon share similarities since the North comprises the states of Acre, Amazonas, Amapá, Pará, Rondônia, Roraima, and Tocantins, which represent seven of nine states in the Legal Amazon.

As shown in Figure 2, these populations are in relatively close proximity to the Legal Amazon's hydroelectric plants that are connected to the interconnected system. In fact, many municipalities in other parts of the country are served by these same plants, despite being located further away. So, it seems clear that distance is not the main reason that four million people in the Legal Amazon are not connected to the interconnected system. Issues such as difficult access, even over short distances, can influence their lack of connection. In addition to logistical factors, environmental and economic issues also play a part in this scenario.

Although the states of the Legal Amazon were responsible for 25.7% of Brazil's electricity generation in 2020, they consumed only 8.4% of the total electricity generated nationally – less than a third of what they generated (EPE 2021).[4] Nevertheless, even with the Legal Amazon generating much more energy than it consumes and making it available to the entire country via interconnected system, more than 14% of its own population does not have access to this energy.[5] As shown in Figure 3, more than 34% of Brazil's installed hydropower capacity is located in the states of the Legal Amazon.

Figure 3. Generation Capacity of Brazil and the Legal Amazon, 2022



Source: *CPI/PUC-Rio, based on data from SIGA (Brazilian Electricity Regulatory Agency - ANEEL), 2022*

4 According to the 2021 Statistical Yearbook of Electricity, in 2020, the states of the Legal Amazon generated a combined total of 159,592 GWh of energy and consumed 52,189 GWh, while Brazil generated 621,219 GWh and consumed 475,648 GWh. Thus, the energy generated in the states of the Legal Amazon divided by the total generated nationally is 25.7%; the total consumed by the states of the Legal Amazon divided by the total generated nationally is 8.4%.

5 Population of the Legal Amazon: 28.1 million (Santos et al. 2021); Population using isolated systems: around 3 million (EPE 2022).

This 14% of the population of the Legal Amazon lives under very different electricity conditions than the rest of the country. Considering only the North Region, 20% of the population is not connected to the interconnected system. As the Brazilian Energy Research Office (*Empresa de Pesquisa Elétrica* - EPE) pointed out in its most recent service planning report on isolated systems (EPE 2022), the supply of diesel fuel to isolated systems is frequently interrupted during periods of drought since it is often transported by river, which means that the power plants of some isolated systems require fuel storage.[6]

Figure 2 shows that many of the isolated systems – primarily in the state of Amazonas – are located along rivers, which means that they are particularly vulnerable to river transport conditions since the primary mode of transport is by river. In Roraima, some isolated systems that are difficult to access also rely on river transport. Meanwhile, the states of Acre and Rondônia have only a few communities where river transport is the only option.

There are thus two Brazils: the one that runs on renewables and can transmit electricity across vast distances, and the one that is isolated and runs on diesel fuel.

This inequality in electrification could be a symptom, as much as a cause, of the various socioeconomic problems affecting the Brazilians who live in these areas. Understanding that these two Brazils exist, the effects on four million people that are disconnected, and how to solve these problems are essential for the isolated populations and for the country's environmental and energy outlook.

Although the electricity consumed in isolated systems represents just 0.6% of Brazil's total consumption (EPE 2021), the cost of this energy is much higher, due to the cost of diesel and the complex transportation and storage logistics of the isolated systems.

Preventing consumers of the isolated system from paying electricity bills above the national average means that the additional costs are absorbed by the rest of the country's population through resources within Fuel Consumption Fund. This ensures that people using the isolated systems do not pay more than those connected to the interconnected system.

6 Population of the North Region: 18.9 million (IBGE 2021).

THREE TYPES OF ELECTRICITY CONSUMERS IN THE LEGAL AMAZON

Brazil has the **interconnected system grid (*Sistema Interligado Nacional* - SIN)** that connects most states and municipalities to the national thermal, hydroelectric, and wind plants, thus integrating the generation and transmission of electricity with the end consumer.

The Legal Amazon, meanwhile, also has what are known as **isolated systems**. These are places that are not connected to the interconnected system and get their energy from power plants – primarily thermal plants running on diesel fuel – which serve the isolated systems exclusively. So, in theory, the populations using isolated systems have full access to electricity.[7]

Isolated systems vary in location, size, distributor, and energy load, but are mostly supplied by thermal plants running on diesel fuel. For example, according to the 2021 edition of the EPE's "Isolated Systems Service Plan - Outlook 2022-2026 (*Planejamento do Atendimento aos Sistemas Isolados Horizonte 2022/2026 – Ciclo 2021*)," the municipality of Boa Vista (Roraima state), which is served by Roraima Energia, is an entirely isolated system supplying electricity to around 436,000 people. It is also connected to other municipalities in the state: the Boa Vista system delivers electricity from the isolated system of Boa Vista to the other municipalities. Meanwhile, in Maici, in the district of Porto Velho (Rondônia state) Energisa Rondônia serves just 15 people. Isolated systems thus vary widely. They exist in urban and remote areas, serving different population sizes and energy demands.

For isolated systems located in areas that are difficult to access, diesel fuel is typically brought to the thermal plants by river on barges or through a combination of land and river transport.

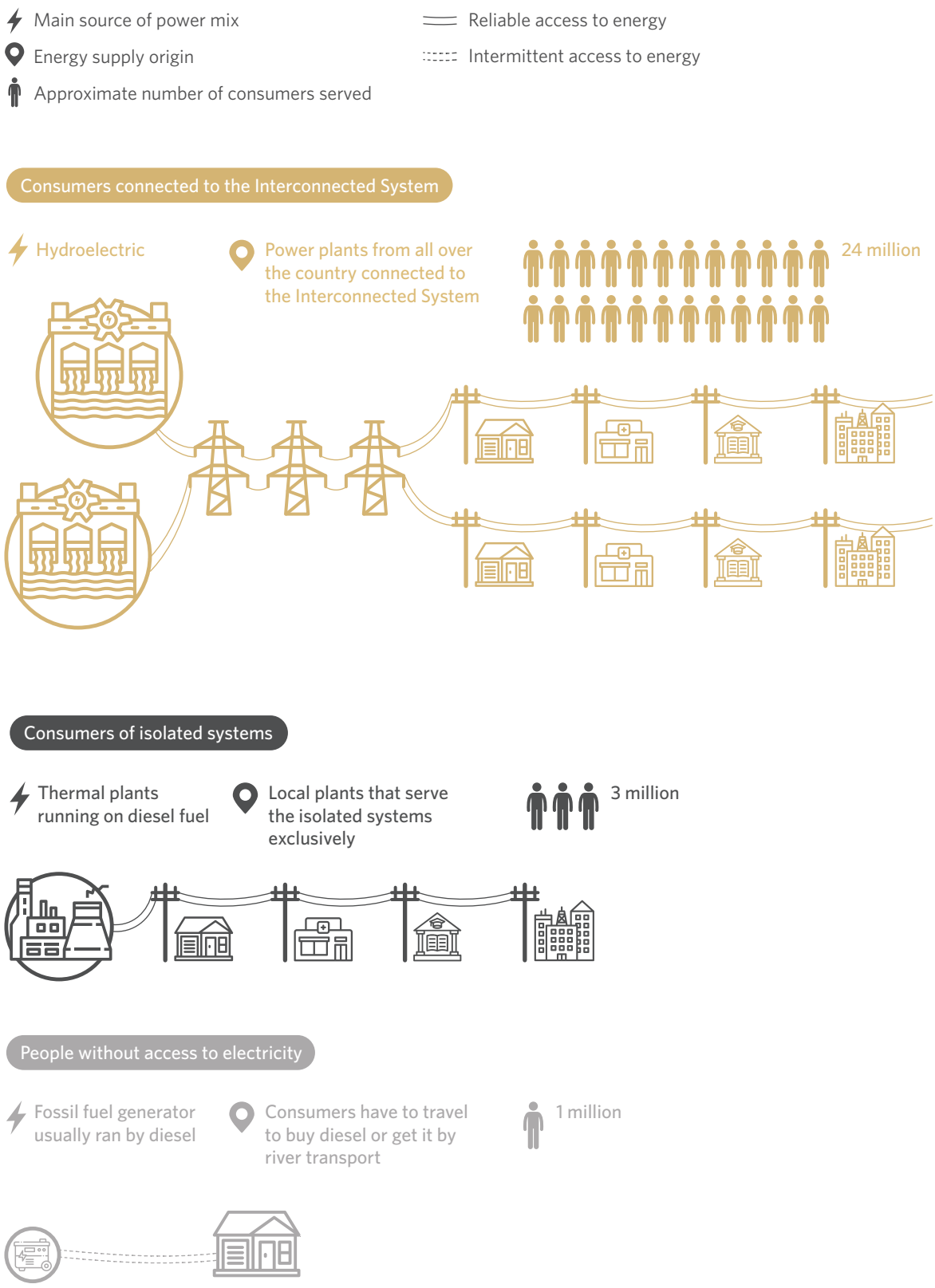
There are still populations that are not connected to either the interconnected or isolated systems – **people without access to electricity**. They live in areas that are difficult to access, so it is not only tough to connect them to the interconnected system, but also a major challenge to build local power plants (to set up isolated systems). These people have intermittent access to electricity since they get their energy — usually diesel — by a river, which means they have to travel to get it. The diesel they purchase is limited, and when it is used in fossil fuel generators, they enjoy just a few hours of electricity per day.

These three types of electricity consumers are present in the Legal Amazon: those connected to the interconnected system, those connected to isolated systems, and those without access to electricity.

Figure 4 describes the three types of electricity consumers in the Legal Amazon by power mix, supply origin, number of consumers, and reliability.

7 There is also an isolated system located outside of the Legal Amazon: Fernando De Noronha (state of Pernambuco).

Figure 4. The Three Types of Consumers and Categories of Electricity Supply in the Legal Amazon, 2019



Source: *CPI/PUC-Rio, based on data from EPE, IBGE and IEMA, 2022*

ISOLATED SYSTEMS

MAIN POINTS

The transmission lines of the interconnected system extend to the Legal Amazon to bring energy from its power plants to the rest of the country, but not to connect all the municipalities and communities within the region.

- Distance is not the primary reason why the isolated systems are not connected to the interconnected system– many isolated systems are located close to hydroelectric and thermal plants on the interconnected system. The issues may be logistical, environmental, economic or political.
- On average, the municipalities using isolated systems perform worse on a variety of socioeconomic indicators compared to both the regional average and the averages of their respective states.
- Since the energy on the isolated systems is subsidized by the Fuel Consumption Fund and thus raises costs throughout the country, energy transition in the Amazon is a positive move for the environment and it will also result in lower electricity bills for all Brazilians. In 2022, the estimated value of the Fuel Consumption Fund is over R$ 10 billion (EPE 2022), which amounts to a per capita subsidy of more than R$ 3,000 per consumer of isolated systems.

ISOLATED SYSTEMS

How is electricity distributed in Brazil? Most states and municipalities are connected to hydroelectric, thermal, and wind plants on the interconnected system (known in Portuguese as the *Sistema Interligado Nacional*, or SIN). This system guarantees that its vast transmission network supplies electricity to connected locations in a secure and uniform way, even across great distances. Hydropower plants generate most of the energy, but in case of adverse hydrological conditions, thermal plants guarantee a reliable supply.

What are isolated systems? These are places that are not connected to the interconnected system, concentrated primarily in the North Region of Brazil. They are connected to energy generators that serve only their individual isolated systems.

How are these locations supplied? The energy demands of the isolated systems are primarily met by thermal plants that run on diesel fuel (97%), which is expensive and highly polluting (EPE 2021b). These plants serve only the isolated systems in the area, and the electricity is delivered to these populations by energy distributors.

How does the diesel get to these locations? In many cases, especially for the isolated systems that are most difficult to reach, the diesel is transported by river, on barges, or by a combination of land and river transport.

Who pays for this consumption? Anything more than the national average energy cost is distributed evenly throughout the country. This ensures that people served by isolated systems do not pay more than those who live in areas connected to the interconnected system.

How many isolated systems are there? In 2018, there were 269 isolated systems in the Legal Amazon. By 2021 that number had fallen to 250.

How many people live in isolated systems? Around three million consumers.

Who produces the energy used in the isolated systems? Parent companies of power plants, biofuels, or other energy solutions participate in an auction to win service contracts for specific projects. The company offering the lowest price for energy supply wins the auction. Energy is also supplied by distributors themselves through direct operations or lease agreements.

HOW ISOLATED SYSTEMS ARE SERVED

Isolated systems are served in three different ways: through the purchase of machinery by the local distributor itself, which then becomes responsible for plant operations and maintenance; through lease agreements; or through contracts awarded to independent energy producers as the result of auctions.

According to the EPE (2022), 77% of isolated systems are served by agents awarded contracts by auction.

Companies interested in supplying isolated systems participate in auctions regulated by the National Electric Energy Agency (Agência Nacional de Energia Elétrica - ANEEL), where the bidding represents the price per megawatt hour to be paid by the company. The company that offers the lowest bid wins the auction since it will serve the specific project for the lowest price. Any power mix can be used (including a combination of sources), and all are subject to the conditions that apply to the bidding.[8]

In the first round of bidding, the competing companies make their bids, and the lowest bid is identified. If there are bids from other companies that are equal to or less than 105% of the winning bid, a second round of bidding is held.[9]

A common critique of this auction model for isolated systems is that it is difficult for renewable energy sources to compete for service contracts. This is due to the higher initial acquisition costs of these sources, greater exposure to exchange rate fluctuations, and storage difficulties, even though they represent lower costs in the long term. Moreover, some auctions do not even allow hybrid models.

For example, in a hypothetical scenario where there is 18 MW of energy demand and 10 average MWm of consumption, the cost of adopting diesel fuel for isolated systems would be R$ 60 million, while the cost of installing solar and battery energy could reach R$ 490 million. However, operating a diesel plant for 25 years would cost R$ 2.3 billion, whereas a renewable system would cost just R$ 4.4 million over the same period (Roraima Renewable

8 A lot usually contains a set of isolated systems that are located near each other.
9 For more information, the 2021 auction notice is available at: bit.ly/3KyoyvJ.

Energy Forum 2022). In an effort to promote renewable sources, the supply periods are usually longer for renewable sources or natural gas than for fossil fuels.

Even so, most isolated systems continue to be served by companies that use diesel since the auction model does not value environmental criteria. Indeed, 97% of the power installed in isolated systems in 2018 was from thermal plants running on diesel fuel (EPE 2018).

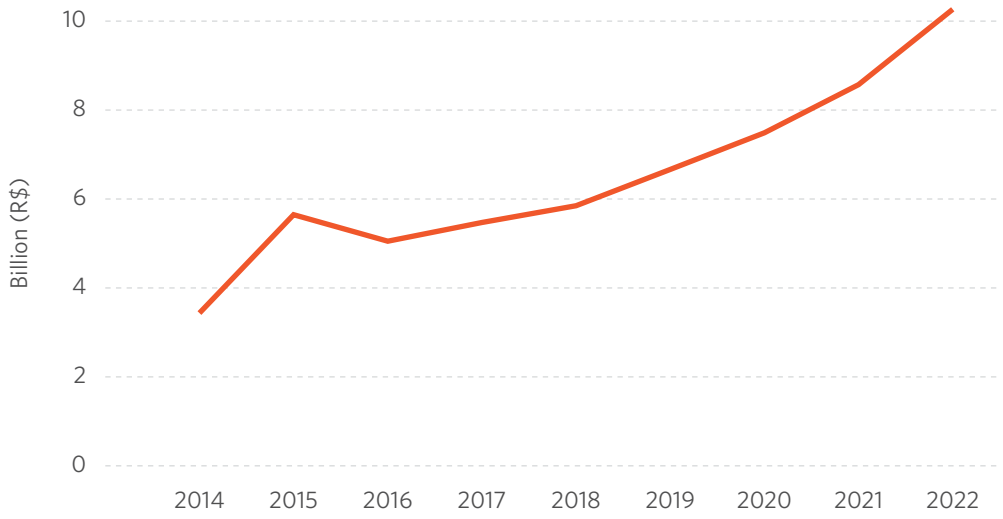
State Sales Tax (*Imposto sobre Circulação de Mercadorias e Serviços* - ICMS) presents another issue for the high rate of diesel. The use of this fuel is clearly an important source of state's revenue. There is thus a hidden incentive to adopt diesel for the isolated systems since the state collects more taxes from this energy source.[10]

As such, although isolated systems account for just 0.6% of national energy consumption, they emit the equivalent of 9% of the greenhouse gases emitted by the interconnected system (EPE 2021).

FUEL CONSUMPTION FUND

The Fuel Consumption Fund subsidizes the costs of electricity generation in isolated systems since the costs in this system are more expensive than the interconnected system (because the isolated systems use diesel fuel and do not enjoy the same economy of scale). The subsidy corresponds to the difference between the energy generation costs of thermal power on the isolated systems and the costs of the same amount of electricity under the Regulated Contracting Environment (*Ambiente de Contratação Regulada*) on the interconnected system. Therefore, on average, consumers of the isolated systems pay practically the same amount for energy as consumers of the interconnected system.

Figure 5. Changes to the Cost of the Fuel Consumption Account, 2014–2022



Source: *CPI/PUC-Rio based on data from the Chamber of Electric Energy Commercialization (Câmara de Comercialização de Energia Elétrica - CCEE).*

10 The ICMS on diesel is 25% in Amapá, 18% in Maranhão, 18% in Amazonas, and 17% in Acre, Pará, Rondônia, and Roraima (FECOMBUSTÍVEIS 2022).

Figure 5 shows that funding for the Fuel Consumption Fund is expensive and has increased over time. This finding is not obvious, given the growing trend to link the isolated systems to the interconnected system.

In 2022, the estimated value of the Fuel Consumption Fund is over R$ 10 billion, a nominal increase of more than 250% since 2013 (EPE 2022). Since around three million people live in isolated systems, **in 2022, there will be a subsidy of R$ 3,000 per consumer of the isolated systems** from Fuel Consumption Fund resources alone.

Since the Fuel Consumption Fund receives its resources from the Energy Development Fund (*Conta de Desenvolvimento Energético* - CDE), which is itself primarily funded by consumers (its costs are passed on as sectoral charges on their electricity bills), consumers throughout the country are impacted by the existence of the isolated systems. Thus, when more diesel fuel is consumed in the isolated systems (and when there are more isolated systems), consumers throughout the country pay more to subsidize the energy consumed in the isolated systems.

The EPE has a planning report to link the isolated systems to the interconnected system. Local distributors assist the EPE in this process, providing relevant information about the isolated systems, such as energy demand and local logistical challenges. This information is not easy to obtain, consequently, the process of linking the isolated systems to the interconnected system is slow and inefficient. Indeed, the EPE states that for the 2021 edition of the Isolated Systems Service Plan - Outlook 2022-2026, "the EPE had to perform extensive due diligence alongside the companies to adapt and supplement the information presented."

ISOLATED SYSTEMS COMPARED TO THE REST OF THE LEGAL AMAZON

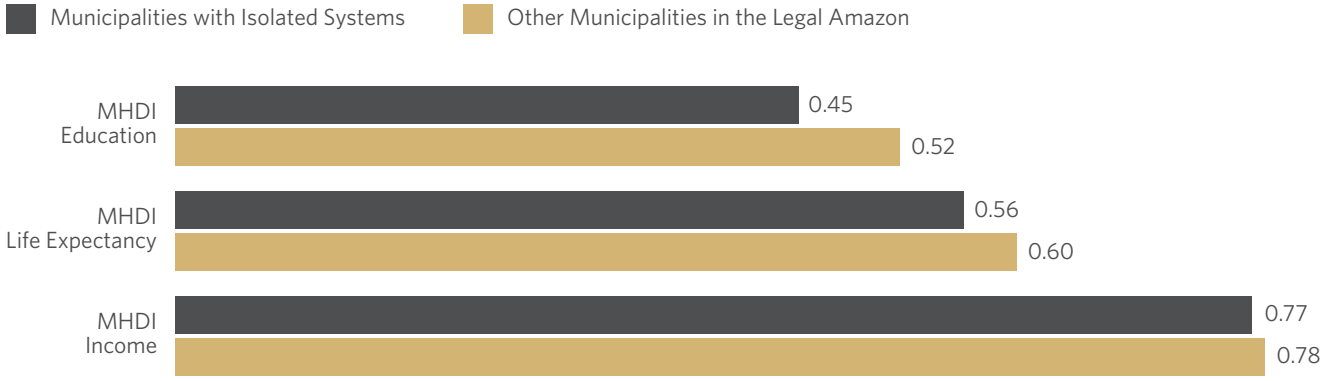
- Lower score on the Human Development Index, as well as on its individual categories (education, life expectancy, income)
- Lower score on the Social Progress Index, which assesses human development
- Lower value added per capita in the agricultural sector
- Lower value added per capita in the service sector
- Lower value added per capita in the industrial sector
- Greater value added per capita in the government sector
- Higher unemployment rates
- Lower basic sanitation rates
- Lower Gross Domestic Product per capita
- Fewer medical facilities per capita
- Higher illiteracy rates
- Lower average on the Basic Education Development Index (IDEB), which indicates a lower quality of basic education

- Lower rate of urban population
- Higher rate of low-income population

Figure 6 shows that the municipalities in the Legal Amazon using isolated systems score lower on all categories of the Municipal Human Development Index than the other municipalities in the Legal Amazon.

But it is important to note that income varies less than the other factors, while there is a greater disparity in education and life expectancy between municipalities with and without isolated systems.

Figure 6. Disaggregation of the Municipal Human Development Index (MHDI), 2010



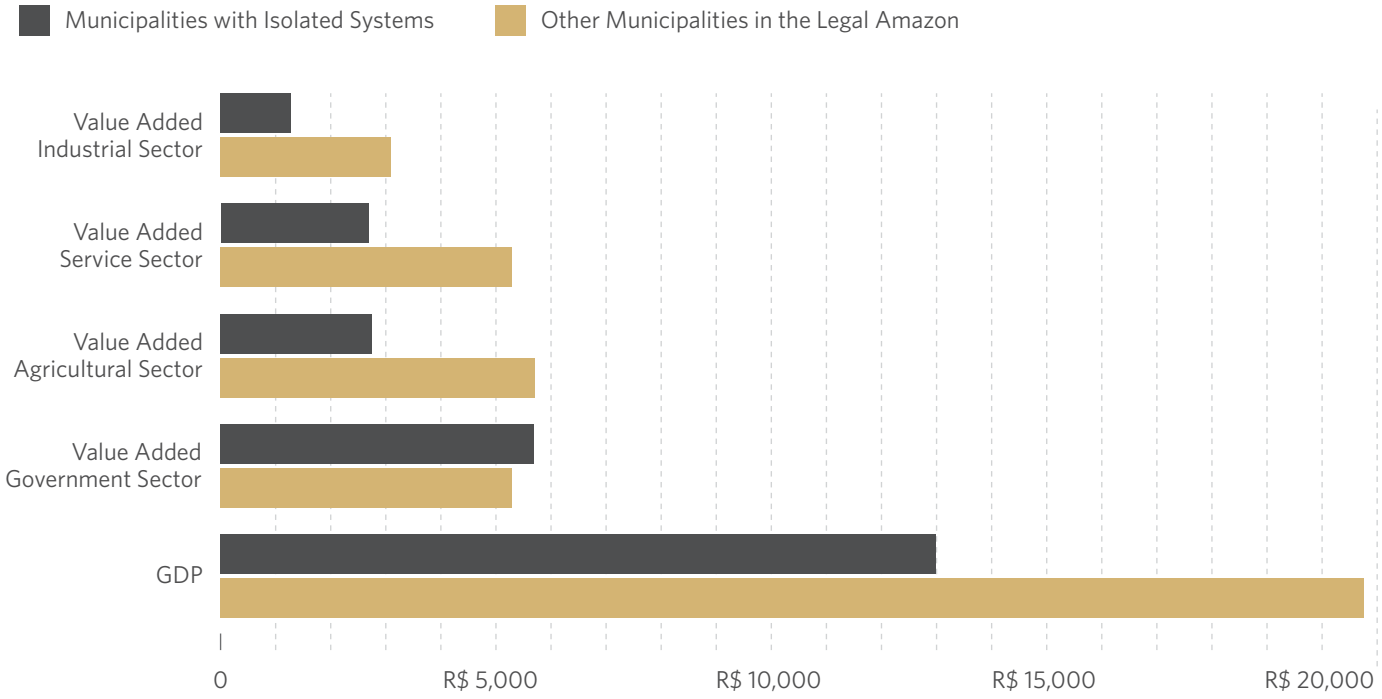
Source: *CPI/PUC-Rio based on data from the United Nations Development Program, 2022.*

The Social Progress Index is an indicator that aims to assess the quality of life, health, and well-being of the population, focusing on the non-economic dimensions of social performance. It measures basic human needs, foundations of wellbeing, and social opportunity and is, therefore, an important indicator of socioeconomic development. Municipalities with isolated systems score worse, on average, on the Social Progress Index. This suggests that these municipalities, on average, have a lower level of human development.[11]

Figure 7 indicates that the average per capita GDP of municipalities in the Legal Amazon without isolated systems is 45% higher than municipalities with isolated systems. However, this disparity is inconsistent when GDP is disaggregated by sector.

11 Originally formulated on a national scale by Social Progress Imperative in 2013, the SPI was adapted by Brazilian research institute Imazon on a sub-national scale and applied to all the municipalities of the Legal Amazon, using 43 social and environmental indicators grouped into 12 components – such as personal safety, ecosystem sustainability], and access to advanced education – which are divided into three dimensions: Basic Human Needs, Foundations of Wellbeing, and Opportunity. The index is calculated by taking the simple average of all components. The data on SPI was extracted using Data Zoom (PUC-Rio).

Figure 7. Per Capita Gross Domestic Product by Sector (R$), 2018



Source: *CPI/PUC-Rio, based on data from IGBE, 2022*

Since GDP can be calculated by taking the sum of the value added of the various economic sectors, the primary sectors are clearly more important and hold more weight in the GDP calculation.

Municipalities with isolated systems also have worse indicators per capita in the agricultural, industrial, and service sectors compared to municipalities without isolated systems, but they have better indicators per capita in the government sector. This difference is most marked in the industrial sector, where the average per capita value added of municipalities of the Legal Amazon without isolated systems is 166% higher than that of municipalities with isolated systems.

This is somewhat surprising, given that four of the seven state capitals in the North Region are in isolated systems: Boa Vista (Roraima), Porto Velho (Rondônia), Belém (Pará) e Macapá (Amapá). It is worth noting, meanwhile, that the municipality of Boa Vista is the only one that operates entirely on an isolated system, whereas the municipalities of Porto Velho, Belém, and Macapá use isolated systems but are also partially connected to the national grid.

An analysis of indicators related to health and education reveals that average levels of health and education are lower in municipalities in the Legal Amazon with isolated systems than in those without. The Basic Education Development Index and the number of medical facilities per person are lower in municipalities with isolated systems, while the illiteracy rate is higher (IBGE 2012, INEP 2019, and DataSUS).

In municipalities with isolated systems, most of the population lives in rural areas, on average, than in municipalities without isolated systems. In the Legal Amazon, an average of 47% of the population of municipalities with isolated systems live in rural areas, while only around 42% of the population of the other municipalities live in rural areas (IBGE 2012).

An analysis of these findings, along with the lower value added per capita of the agricultural sector in municipalities with isolated systems (as shown in Figure 7) indicates that agricultural productivity would likely be lower in municipalities with isolated systems than in other municipalities in the Legal Amazon.

Finally, municipalities with isolated systems have, on average, a higher concentration of low-income individuals (defined as people whose income is below the municipality's average minimum wage) (IBGE 2012).

This higher concentration of low-income individuals in municipalities with isolated systems is consistent with the other findings, which indicate lower social and economic levels.

WHAT EXPLAINS THESE FINDINGS?

It is important to understand that the populations living in isolated systems have, in theory, full access to electricity. Passed on December 9, 2009, Law 12.111 is considered the regulatory benchmark of the isolated systems and it establishes that their operators must serve everyone in their markets. Also, Decree 7246, issued July 28, 2010, regulates the legal benchmark and states that vendors of electricity should first propose energy and power supply solutions, to be evaluated by the EPE.

So as far as regulations are concerned, the isolated systems receive a sufficient supply of electricity. Which means that by simply being in an isolated system should not directly affect a municipality's socioeconomic indicators.

Even so, municipalities with isolated systems have worse indicators compared to the rest of the Legal Amazon listed above. It is therefore possible that using an isolated system, although it does not directly affect the economy, is indicative of other issues affecting the municipality.

Another factor that reflects this reality is energy consumption. Although the average consumption per subsystem in the North Region is nearly 443 kWh per month, on the isolated systems it is just 291 kWh (EPE 2021).

Hypothetically, it can be considered that municipalities in isolated systems are generally further away from main state and federal highways. This would negatively affect their economies in different ways, given the difficulty of transporting workers, supplies, and finished products – which makes the economies in these locations unattractive. This is a feasible explanation since there could be a correlation between the difficulty of connecting a location to the national grid and the difficulty of accessing the location.

One way to verify this would be to compare the average distance between the isolated systems and the main state and federal highways to the average distance between those same highways and the other municipalities in the Legal Amazon.

This logic, which links the presence of isolated systems to greater difficulties accessing a municipality, could, by extension, also suggest that there is less state authority on the whole in these locations. The quality of education (e.g., lower scores on the Basic Education Development Index and higher illiteracy rates) and healthcare (e.g., higher number of people per hospital) would thus also be negatively affected.

That suggests that municipalities do not perform worse on the various socioeconomic indicators merely because they are in isolated systems, but instead due to the factors that left them unconnected to the national grid in the first place.

Another possibility would be that the quality of the energy supply is not as good as what is delivered to municipalities on the national grid. A poor-quality energy supply harms an economy in numerous ways. For example, it affects industrial and trade activities and services. This reasoning finds support in the justification given by the Energy Research Office for holding transmission auctions to connect a region: that integrating a region onto the national grid brings quality and reliability to the energy supply, creating substantial improvements to electricity services as well as allowing the region to stop using local thermal generation.

Therefore, if isolated systems have access to poor-quality energy (with frequent and prolonged interruptions), the communities that use them could be expected to perform worse on the various socioeconomic indicators. One way to verify this would be to compare changes over time to the socioeconomic indicators of municipalities that stopped using isolated systems versus the ones that kept using them.

If the municipalities that stopped using isolated systems showed significantly greater improvement in their socioeconomic indicators than those that kept using them, it would be possible to estimate the effect that using isolated systems has on a municipality, for the indicators studied.

Similarly, to verify the hypothesis that municipalities with isolated systems are supplied with poor-quality energy, these municipalities' qualitative indicators of energy supply could be compared to those of the municipalities that do not use isolated systems. If there is a significant difference in the System Average Interruption Frequency and Duration Indexes (which measure the frequency and duration of power interruptions) between municipalities on the interconnected system and those served by isolated systems, this would indicate a difference in the electricity supply.

STATE-BY-STATE ANALYSIS OF ISOLATED SYSTEMS

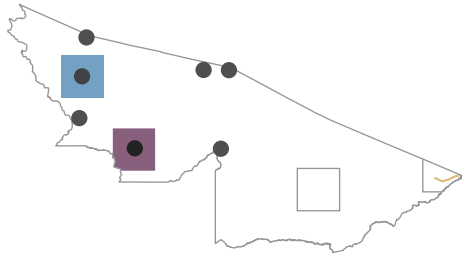
In 2018 there were nine isolated systems in Acre; 29 in Amapá; 95 in Amazonas; 23 in Pará; 25 in Rondônia; 86 in Roraima; and two in Mato Grosso. The study verified that the municipalities with these isolated systems perform worse, on average, than the regional average on the primary socioeconomic indicators.

It is still possible that these municipalities do not perform worse than the average of the states in which they are located, even when they perform worse, on average, than the Legal Amazon as a whole.

A hypothesis test was conducted to see how much the performance of municipalities with isolated systems deviated from that of the other municipalities for the indicators studied, in their respective states as well as for the combined municipalities of the Legal Amazon.

Table 1. Statistical Significance of Socioeconomic Indicators Used to Compare Municipalities With and Without Isolated Systems in the Legal Amazon

How to read the table:



- Isolated Systems
- Municipality with Isolated Systems, whose indicators are significantly **lower** compared to the other municipalities in the same state
- Municipality with Isolated Systems, whose indicators are significantly **higher** compared to the other municipalities in the same state
- Other Municipalities (without Isolated Systems)
- Interconnected System

Indicators	**States**					
	Acre	Amapá	Amazonas	Pará	Rondônia	**Legal Amazon**
MHDI Education	●		●			●
MHDI Life Expectancy	●		●	●		●
MHDI Income	●		●		●	●
AV Industrial pc			●			
AV Service pc			●			●
AV Agriculture pc	●					●
AV Government pc	●			●		●
GDP pc	●		●			●
Unemployment Rate						
Medical Facilities pc						●
Illiteracy Rate	●		●			
Low-income Population Rate	●		●	●		●
Urban Population Rate		●	●			●
Basic Sanitation Rate	●		●			
IDEB	●					●
SPI			●			

Legend:

- ● Indicator significantly **lower** for municipalities with Isolated Systems
- ● Indicator significantly **higher** for municipalities with Isolated Systems
- ● Statistically non-significant

IDEB	Basic Education Development Index
MHDI	Municipal Human Development Index
SPI	Social Progress Index
AV	Added value
pc	per capita

Source: *CPI/PUC-Rio, based on data from IBGE 2010 and 2018, DataSUS 2018, INEP 2019, PNUD 2010, and IPS 2018 and 2022*

The level of confidence adopted was 95%, and the findings are reported in Table 1. If a given indicator for any state appears at the far left of the distribution, which contains 2.5% of the total density, it is shown in blue in Table 1. This means that the municipalities with isolated systems perform significantly worse on that indicator than the other municipalities in that same state.

Similarly, the indicators for a given state that appear at the far right of the distribution, which contains 2.5% of the total density, are shown in purple. This suggests that the municipalities in isolated systems in that state perform significantly better on that indicator than the other municipalities in the same state.

The right-hand column shows the statistical significance of the indicators for the Legal Amazon. Roraima is not included in this analysis since the state does not have any municipalities connected to the national grid. Mato Grosso, meanwhile, had just two isolated systems in 2018 and currently has only one, so it is not included, either.[12]

From Table 1 it may be concluded that the states of Amazonas and Acre have the most significant disparity between municipalities with and without isolated systems for the greatest number of socioeconomic indicators. It is worth noting that in 2018, Amazonas had more isolated systems than any other state, followed by Roraima.[13] Therefore, the findings related to the state of Amazonas carry a lot of weight in the analysis of the isolated systems of the Legal Amazon as a whole.

Evaluating all states of the Legal Amazon, the Human Development Index is significantly lower in municipalities with isolated systems. Furthermore, there is also lower per capita GDP, lower value added per capita for agriculture and the service sector, lower percentage of the population living in urban areas, fewer medical facilities per person, a higher rate of low-income, and lower scores on the Basic Education Development Index. The government's value added per capita was the only indicator that was significantly higher for municipalities in the Legal Amazon with isolated systems.

It is thus clear that whether municipalities are compared to others within the same state, or to the Legal Amazon, they demonstrate, on average, worse socioeconomic development in multiple areas.

The possibility remains that the effects recorded reflect the significant overlap between municipalities with isolated systems and those with people who lack access to electricity. Appendix 1 shows the same statistical test as in Table 1but excludes municipalities containing people without access to electricity.

12 The report "Potential Implementation Risks in the Pilot Energy Efficiency Auction in Roraima" (Schutze et al. 2020) details the energy specifics of Roraima.

13 In 2018, the states of Amazonas and Roraima had, respectively, 95 and 86 isolated systems, amounting to over 67% of all isolated systems in the Legal Amazon.

PEOPLE WITHOUT ACCESS TO ELECTRICITY

MAIN POINTS

- Nearly a million people in the Legal Amazon lack access to electricity, which has important consequences across a broad range of areas including production, healthcare, safety, education, and combatting deforestation.
- One solution is decentralized power generation by photovoltaic systems, which are better than small diesel or gasoline generators, in both environmental and economic terms.

In addition to the isolated systems, there are populations that still lack reliable energy access.

The Institute for Energy and the Environment (IEMA) estimates that 990,103 people in the Legal Amazon lack access to electricity – nearly 3.5% of the region's population. This number was calculated using a georeferencing method: starting with the areas not covered by the national grid (and therefore potentially without electricity), areas with isolated systems were excluded, along with places that had a high density of roads (since distribution lines tend to follow roads), and places where the 2010 Population Census reported that at least 99% of households were served. The remaining areas were thus considered to be lacking access to public energy services.

According to IEMA, Pará is the state with the greatest number of people lacking electricity (409,593), while Acre has the highest percentage of the population lacking access to electricity. 10%.

Electricity is needed for many activities that contribute to the quality of life. In terms of healthcare, access to electricity makes it possible to refrigerate medications, vaccines, and food. Likewise, internet access allows reporting illegal deforestation in these areas. Electricity also enables people to turn lights on at night, to pump drinking water, and to use computers in schools. Thus, electricity is key to the quality of life, and its absence is responsible for several socioeconomic issues.

Yet it is crucial to understand that the populations in these areas do not live entirely without energy. In most cases, they use small generators for a few hours a day. What characterizes them as "without access to electricity" is that the government does not provide a mechanism for reliable energy access, unlike in the isolated systems.

The generators run on diesel fuel or gasoline that must be transported to these areas. Since these areas are not easy to access, this transport is not easy to carry out. Another problem with this supply method is that the generators create a noise pollution as well as the air pollution caused by burning fossil fuels.

This scenario greatly diminishes the possibility of exploring natural resources in a sustainable way. The lack of electricity makes it difficult to develop sustainable productive sectors, such as bioeconomy, and it forces local populations to use available resources in an

unsustainable way. Access to electricity could promote productive activities that make standing forests more valuable.

One possible solution would be to bring renewable energy — especially photovoltaic solar — to these areas. This would allow the energy generated by burning fossil fuels to be replaced (or at least supplemented) by clean and renewable energy, which, in the long term, would reduce total energy costs. Initiatives for decentralized generation via photovoltaic systems are an economically and environmentally advantageous solution since the source is renewable and there are no costs for fuel.

Another important factor to consider is the obligations of distributors. ANEEL has established the requirement that distributors comply with specific quality standards related to the amount of undervoltage time considered precarious or critical, as well as the frequency of supply interruptions (PRODIST nd). If distributors perform below the minimum levels defined for these indicators, they face fines and may be required to compensate consumers and power plants. Although the standards vary somewhat to accommodate local challenges, distributors still generally fail to meet them in areas that are difficult to access. It is thus important to consider regulation that would incentivize universal access as quickly as possible while maintaining quality. Too many requirements and standardization could make the process more complicated.

MORE LIGHT FOR THE AMAZON

The National Program for Universalization of Access and Use of Electrical Energy in the Legal Amazon, commonly known as "More Light for the Amazon," was created in February of 2020 with an expected completion date of 2022 (but this may be extended indefinitely). **The goal of the program is to serve families living in remote parts of the Legal Amazon who lack access to public energy services or who receive electricity from non-renewable sources.**

It uses funds from the Energy Development Fund and, depending on the state, from distributors, to provide renewable electricity access to populations living in remote areas. Under the program, riverside, indigenous, and quilombola communities would gain access to renewable electricity.

However, the structure of the program does not establish any fines or consequences in case objectives are not met. The project also lacks monitoring capacity, so effective implementation is not adequately assessed.

Another criticism of the program is that there is little interaction between distributors and local communities. NGOs and civil society – which are familiar with the challenges and the reality on the ground – could play a role in communicating the real needs of these populations to the appropriate entities in the energy sector. A report by the Institute for Climate and Society in collaboration with the Renewable Energy Forum of Roraima (2022) points out that the success of the program depends upon the active involvement of local communities.

More Light for the Amazon has replaced the "Light for All" program (*Luz para Todos*), which also used Energy Development Fund resources and connected more than 16 million people without access to electricity in Brazil (Eletrobras 2017). That program connected most Brazilians who lacked access to electricity, so More Light for the Amazon was

created to serve most of those who were not connected by Light for All, who are located in the Legal Amazon.

In 2020, Congressional Bill nº 248 proposed the establishment of a target date for universal access in the Legal Amazon. Under the bill, the federal government would regulate the objectives that energy distributors must reach to meet the goal of universal access. Those who do not meet the deadline would be blocked from adjusting consumer tariffs. ANEEL would have a fixed deadline for regulating the normative actions for the rollout of the universal access program and would also be required to publish updated information on its website regarding the progress of the universal access installations. The Congressional Bill would also earmark more resources to streamline the universal access process.

RECOMMENDATIONS

Create favorable conditions for renewable supply initiatives to compete in the bidding for service concessions in isolated systems, by modifying bidding rules.

Since solar panels cost significantly more in the short term than diesel and are subject to exchange rate fluctuations, among other forms of instability, the current auction model makes it very difficult for renewable initiatives to compete in the bidding.

The fact that renewable sources produce a longer-lasting supply is not enough to make renewables competitive. A price should be put on an energy source's environmental impact during the bidding process.

Promote service for people without access to electricity by creating incentives for decentralized solar power.

There are persistent number of households who still do not have full access to electricity in Amazon. These people live remote areas and have intermittent access to electricity, usually provide by small diesel-powered generators. Implementing decentralized solar power plants could lead to significant environmental gains by reducing emissions of greenhouse gasses related to transport and consumption of diesel fuel.

Improve the More Light for the Amazon Program, by creating clear goals and prioritization criteria, and by incorporating effective oversight and local community involvement.

The More Light for the Amazon Program aims to provide access to electricity in unserved parts of the Amazon. But it appears to lack structure, with no timeline for the implementation of its projects.

Moreover, no monitoring is built into the program, so no one is checking whether the various agents involved are complying with requirements. This makes it impossible to verify the program's success and to identify its flaws or areas for improvement.

Even if there were effective monitoring, it is worth highlighting that distributors involved in the project are barely under any obligation, since there is no penalty for not complying with the requirements. This means that agents who impede the progress of a project do not face any consequences.

Strengthening the project requires more detailed planning information, including plans for monitoring, transparent criteria for prioritization, dates for completion of each step, and consequences in case of noncompliance.

Another key point is that there should be more interaction between distributors and local communities. This would foster better understanding of local needs and lead to the installation of appropriate systems.

REFERENCES

Atlas do Desenvolvimento Humano no Brasil. *O Índice de Desenvolvimento Humano Municipal Brasileiro*. nd. bit.ly/3Me2ZjL.

Câmara de Comercialização de Energia Elétrica (CCEE). *Relatório de Orçamento das Contas Setoriais 2020*. 2019. bit.ly/3xADKUM.

Câmara de Comercialização de Energia Elétrica (CCEE). *Premissas Orçamentárias – Contas Setoriais 2022.* 2021.

Câmara de Comercialização de Energia Elétrica (CCEE). *Contas Setoriais - CCEE.* sd. bit.ly/3KWf5Ox. Access date: March 29, 2022.

DataSUS. *Informações de Saúde*. bit.ly/3FgA8cC. Access date: March 29, 2022.

Eletrobras. *Programa Nacional de Universalização do Acesso e Uso da Energia Elétrica – Luz para Todos*. 2017. bit.ly/3MIYON7. Access date: March 29, 2022.

Empresa de Pesquisa Energética (EPE). *Anuário Estatístico de Energia Elétrica 2021 - ano base 2020*. 2021a. bit.ly/3xDfqSs.

Empresa de Pesquisa Energética (EPE). *Sistemas Isolados de energia no Brasil. O que são e quais suas principais características?* 2021b. bit.ly/34hBoO9.

Empresa de Pesquisa Energética (EPE). *Sistemas Isolados: Planejamento do Atendimento aos Sistemas Isolados Horizonte 2023 - Ciclo 2018.* 2019a. bit.ly/3xwB5LX. Access date: March 29, 2022.

Empresa de Pesquisa Energética (EPE). *Sistemas Isolados: Planejamento do Atendimento aos Sistemas Isolados Horizonte 2024 – Ciclo 2019.* 2019b. bit.ly/3MvIWxG. Access date: March 29, 2022.

Empresa de Pesquisa Energética (EPE). Sistemas Isolados: Planejamento do Atendimento aos Sistemas Isolados Horizonte 2025 - Ciclo 2020. 2021. bit.ly/3rPMt1G. Access date: March 29, 2022.

Empresa de Pesquisa Energética (EPE). *Sistemas Isolados: Planejamento do Atendimento aos Sistemas Isolados Horizonte 2022/2026 - Ciclo 2021.* 2022. bit.ly/3EqoSK9. Access date: March 29, 2022.

Federação Nacional do Comércio de Combustíveis e de Lubrificantes (FECOMBUSTÍVEIS). *Tributação dos Combustíveis por Estado.* 2022.

Fórum de Energias Renováveis de Roraima. *Contribuição à Consulta Pública 120/2022 do MME.* 2022.

Instituto Brasileiro de Geografia e Estatística (IBGE). *Censo Brasileiro de 2010.* 2012.

Instituto Brasileiro de Geografia e Estatística (IBGE). *Amazônia Legal | IBGE.* 2020. bit.ly/3OoD6j4. Access date: March 29, 2022.

Santos, D., R. Salomão and A. Veríssimo. *Fatos da Amazônia 2021 (Facts on the Amazon)*. Amazon 2030, 2021.

Schutze, Amanda, Rhayana Holz and Juliano Assunção. *Potential Implementation Risks in the Pilot Energy Efficiency Auction in Roraima*. Climate Policy Initiative, 2020. 2020.

APPENDIX 1. STATISTICAL TEST EXCLUDING MUNICIPALITIES WHERE THE POPULATION LACKS ACCESS TO ELECTRICITY

It is important to understand that of the 121 municipalities using isolated systems in 2018, 101 of them also had people without access to electricity. Meanwhile, of the 646 municipalities in the Legal Amazon on the national grid only 208 had people without electricity.

This means that there is some overlap between municipalities using isolated systems and people without access to electricity.

Since many municipalities have both isolated systems and people without access to electricity (just as municipalities on the national grid also have people without access to electricity), it is possible that the results of the statistical comparison between municipalities connected to the national grid and with isolated systems are compromised by the presence of people without access to electricity.

Therefore, the lower performance on socioeconomic indicators by municipalities with isolated systems could simply reflect the higher (proportional) presence of people without access to electricity in those cities.

To eliminate that possibility, the same statistical test was performed for the same socioeconomic indicators, comparing municipalities connected to the national grid and with isolated systems, but excluding (from both groups) cities where there were people without access to electricity (in any number).

Table 2. Statistical Significance of Socioeconomic Indicators Used to Compare Municipalities With and Without Isolated Systems in the Legal Amazon, Excluding Municipalities Where People Lack Access to Electricity

Indicators	Legal Amazon
MHDI Education	●
MHDI Life Expectancy	●
MHDI Income	○
AV Industrial pc	○
AV Service pc	○
AV Agriculture pc	○
AV Government pc	○
GDP pc	●
Unemployment Rate	●
Medical Facilities pc	○
Illiteracy Rate	○
Low-income Population Rate	●
Urban Population Rate	○
Basic Sanitation Rate	○
IDEB	●
SPI	○

Legend:

- ● Indicator significantly **lower** for municipalities with Isolated Systems
- ● Indicator significantly **higher** for municipalities with Isolated Systems
- ○ Statistically non-significant

IDEB	Basic Education Development Index
MHDI	Municipal Human Development Index
SPI	Social Progress Index
AV	Added value
pc	per capita

Source: *CPI/PUC-Rio, based on data from IBGE 2010 and 2018, DataSUS 2018, INEP 2019, PNUD 2010, and IPS 2018, 2022*

Table 2 shows that when compared with the findings on Table 1, some indicators are no longer significantly lower for municipalities with isolated systems. Yet these municipalities continue to perform significantly worse in the Municipal Human Development Index categories of education and life expectancy, and also in terms of employment rates, low-income population, and the Basic Education Development Index.

It is clear that the reason for which municipalities with isolated systems perform significantly worse on selected socioeconomic indicators than municipalities connected to the national grid is not directly related to the presence of people without access to electricity in those cities

climatepolicyinitiative.org