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Electrification in Brazil

Deep-Dive Analysis

October 7, 2024

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UAC country deep-dive reports were produced to serve as reference material to accelerate last -mile access. Reports consist of 3 components:

1

Overview of electrification in the country, including history, current status, geographic & demographic trends, and future plans.

Source: Various publicly available data sources; interviews with Coalition members & other partners

2

Summary of a geospatial plan, recommending electrification modalities for target communities in order to achieve 100% electricity access and improve quality of service

Source: Geospatial plans produced by comprising Waya Energy, the MIT-Comillas Universal Access Lab, and/or TTA (authorship varies by country), based on satellite imagery and data inputs from national agencies & other sources

3

Summary of challenges & considerations for operationalizing electrification plans, organized by theme

Source: Interviews with coalition members & other partners; publicly available reports; analysis by Catalyst

DISCLAIMERS

- The geospatial plans are not government-endorsed roadmaps. They are intended as reference material to support future electricity access planning and implementation. As such, they are presented for informational purposes only.
- Each plan is based on modeling that incorporates a specific set of assumptions (including a specific definition of "unelectrified"). Thus, the plans' conclusions may not be directly comparable to those of other electrification analyses for that country.
- Grid densification activities outlined in the geospatial plans are intended to represent business-as-usual operations for utilities, based on expected service improvements & demand growth in communities already electrified today.

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Acronyms and abbreviations

ANEEL - Agência Nacional de Energia Elétrica (Brazilian Electricity Regulatory Agency)
CAPEX - Capital expenditure
CCC - Conta de Consumo de Combustíveis (Fuel Consumption Bill)
CDE - Conta de Desenvolvimento Energético (Energy Development Account)
DisCos - Distribution companies
IBGE - Instituto Brasileiro de Geografia e Estatistica (Brazilian Institute of Geography and Statistics)
LpT - Luz para Todos [program]
MME - Ministry of Mines and Energy
OPEX - operational expenditure
O&M - Operation and maintenance
PV - Photovoltaic
PRODEEM - Programa de Desenvolvimento Energético dos Estados e Municípios (National Program for Energy Development of States)
PUE - Productive use of energy
RE - Renewable energy
RGR - Reserva Global de Reversão (Global Reversion Reserve)
SAIDI - System Average Interruption Duration Index
SAIFI - System Average Interruption Frequency Index
SHS - Solar home system
SIN - Sistema Nacional Interconectado (National Interconnected System)
USAID - United States Agency for International Development
USD - United States Dollar

Current status of electrification and energy access in Brazil

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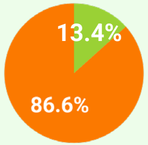
Brazil has a high total electrification rate, but there is still a challenge to provide reliable electricity to the more remote regions of the country.

398,000 people without access to electricity[1]

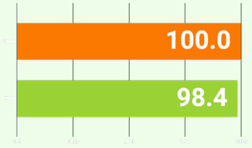
990,000 people without access to *reliable* electricity[2]

212 million[3]
Total population*, with an urban/rural split of:



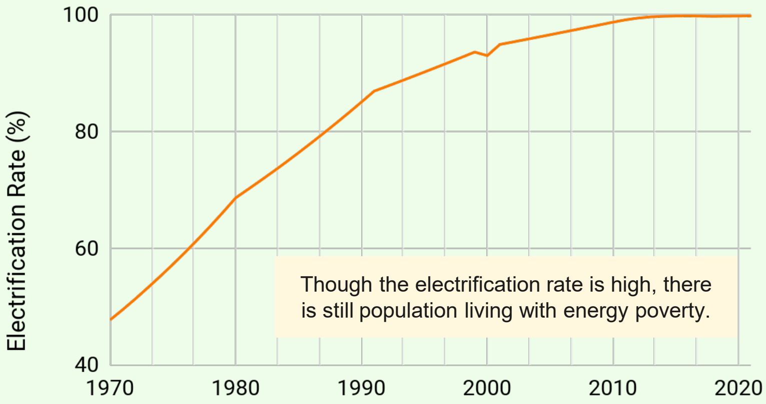
*There is a current population growth rate of 0.04%, reaching 0% growth by 2042

99.8%
Total electrification rate[4], corresponding to **330,000 households** without electricity access.[1]



urban/rural electrification rate (%)

780 kWh
Annual residential electricity demand per capita, compared to the global average of 3,355 kWh.[5,6]



[1] Calculated based on electrification rate reported by IADB. [2]Government metric obtained through interviews with coalition partners. Accounts for all people not connected to the SNI and those who are using diesel generators. [3]Population Data, OLADE, 2021. [4]Access to Electricity Database, IADB, 2021. [5]Calculated based on EPE data for electricity consumption and UN population data, 2023. [6] Calculated based on IEA data for electricity consumption and UN population data, 2021

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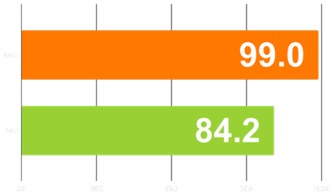
Other indicators provide a glimpse into Brazil's commitment to renewable fuel sources and power reliability.

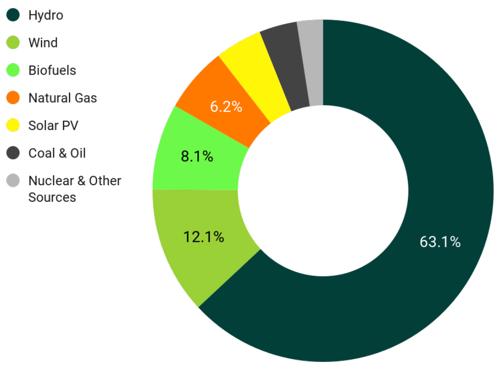
97%

Clean cooking access rate[1] - **2.3 million households** *without* access to clean cooking[2,3]

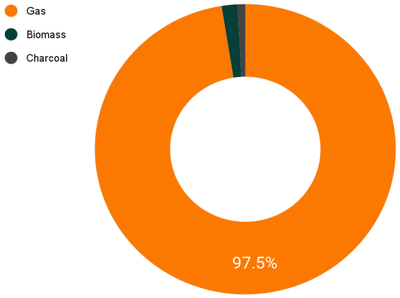


urban/rural clean cooking access rate (%)[1]

Electric grid mix[5]



Breakdown of primary cooking fuels[4]



Grid outages in 2024[6]

Duration of electricity interruptions

10.43
hours/year

Number of electricity interruptions

5.24
times/year

Compared to the world average of 2.8 hours/year and 2.23 times/year in 2019.[7]

[1]Residential Energy Consumption by Income Class, EPE, 2021. [2]World Population Prospects 2021, UNDESA, 2021. [3]Brazil: Average Household Size, GlobalData, 2021. 4 [4]Database: Cooking fuels and technologies (by specific fuel category), WHO, 2021. [5]Anuário Estatístico de Energia Elétrica, EPE, 2023. [6]The results of the performance of distributors in the continuity of the supply of electricity in 2023, ANEEL, 2024. [7] SAIDI/SAIFI, World Bank, 2019

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Geographic and demographic trends

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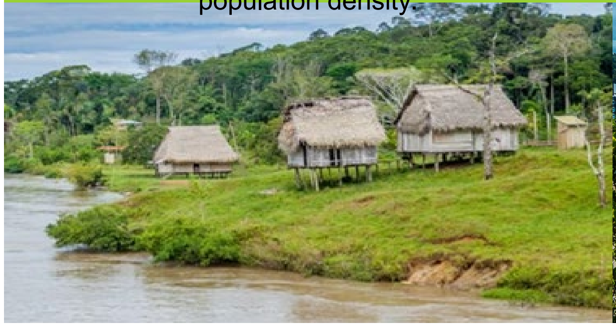
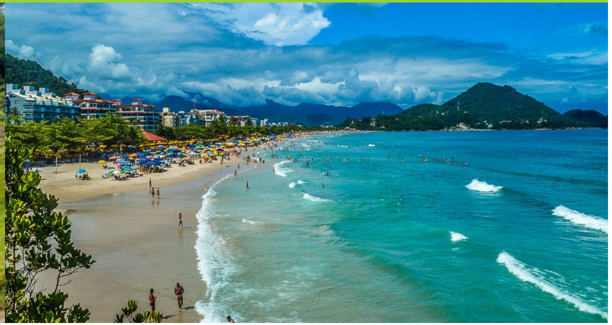
Brazil has two main geographic regions, of which one poses significant service-delivery challenges

[1]

Legal Amazon Region	Coastal Region
Dense jungle, difficult accessibility, and low population density.	Atlantic forest, beaches and dense urbanization.





- The Legal Amazon Region (hereafter referred to as “Amazon”) was established in 2009. It is a political region that receives tax incentives to promote regional development. The area encompasses 5 million km^2, 58% of Brazil’s total land area. [2,3]

[1]Amazonia legal Brazil map, Wikimedia Commons, 2024. [2]Legal Amazon, IBGE, 2024 [3]Implementing REDD in the Brazilian Amazon: Contextualization, Debates and Challenges, The Forests Dialogue, 2009.

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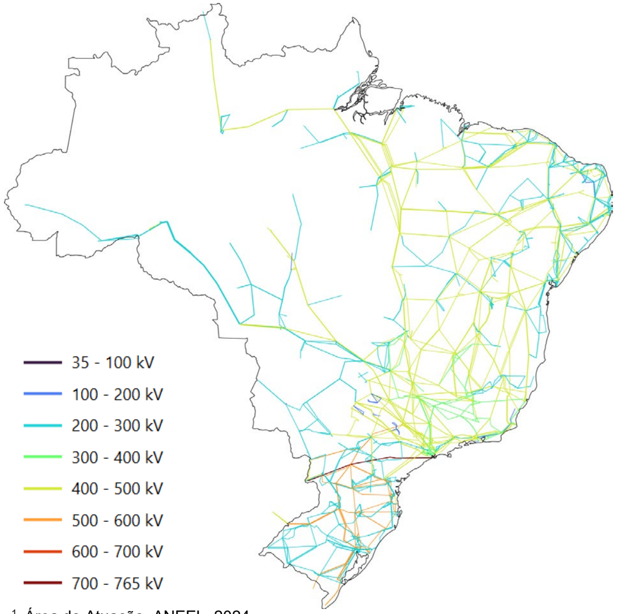
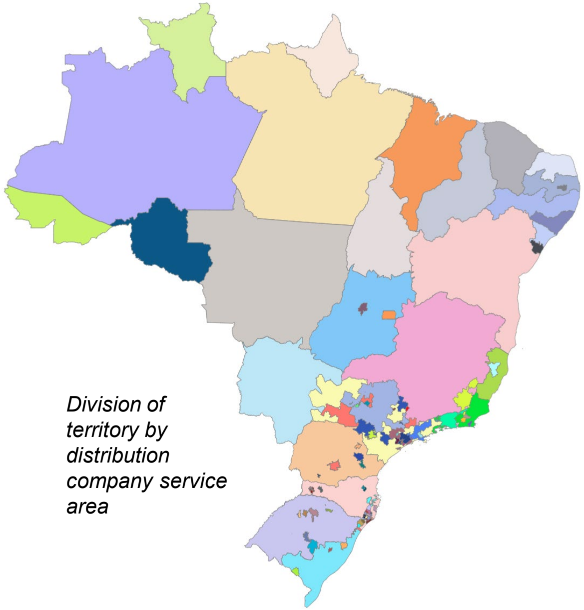
Brazil's coastal region has, by far, the most developed electricity grid network.

GRID NETWORK



DISTRIBUTION COMPANIES



Division of territory by distribution company service area

There are a total of **105** distribution companies in Brazil, with **concessions covering the entire land area**. The largest is

[1] Área de Atuação, ANEEL, 2024

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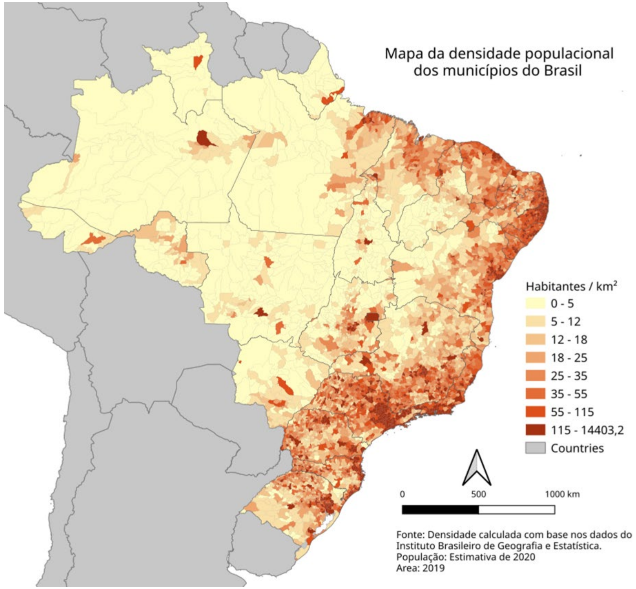
The Amazon is characterized by low population density and abundance of resources

- 95% of Brazil's unelectrified population is located in the Amazon where the population density is, on average, 6.5 persons/km^2, reaching as low as 2 persons/km^2 in the most remote areas .[1,2]
- Many communities are isolated, located in dense rainforests, or along rivers, which raises logistical and technical challenges. Protecting the integrity of the Amazon ecosystem is an added challenge.
- The economies of these regions are largely dependent on resource intensive activities like agriculture, livestock production, and mining, which drive deforestation.[3]
- The area remains the poorest in the country, marked by a trade deficit of over USD 23 billion.[3]



Brazil population density by municipality, 2019

[1] According to IEAM, about 1 million people don't have electricity in the Amazon, IEMA, 2022. [2]Censo 2022, IBGE, 2022. [3]New Economy for the Brazilian Amazon, WRI, 2023.

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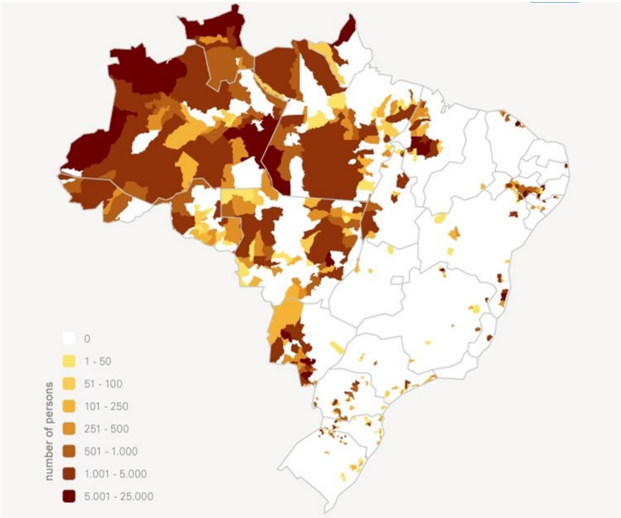
There are significant disparities in energy access across several socio-demographic indicators

- The Amazon was responsible for over 26% of the electricity generated nationally in Brazil in 2020, yet it consumed just 8% of the total generated.[1]
- Over 14% of the population of the Amazon lacks access to the electricity generated on the SIN, meaning about 3 million people obtain electricity from local diesel-powered thermal plants.[1]
- There are significant disparities in terms of sociodemographic characteristics of unelectrified groups.[2]

Share of population without reliable electricity by minority group	
Indigenous territories	19%
Conservation areas	22%
Rural settlements	10%
Quilombola communities	4%



Indigenous persons in Indigenous Lands by municipality, IBGE, 2022

[1] Rivers of Diesel in the Amazon: Why does the Region with Brazil's Biggest Hydroelectric Plants Rely on Expensive, Dirty Fuel?, Climate Policy Initiative, 2022. [2] Cardoso Leite & de Sousa, 2020

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The Amazon tends to have larger households and faster population growth, while workforce indicators are consistent with the national average.

Average household size

3.33 residents

20% higher than national average (2.79)

Population

1% growth rate

Double the national average (0.52%)

Working age population

82% of residents

Lower than the national average (85%)

Economically inactive population

9% of residents

comparable to the national average (9.6%)

Unemployed population

9% of residents

0.6% lower than the national average (9.6%)

Source: National Census, IBGE, 2022

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Nevertheless, development indicators for states within the Amazon lag behind the national average.

State	Share of minority groups	Share of uneducated people	Human Development Index (HDI)	Average monthly income (R$)
Brazil	1.49%	20.6%	0.76	2,582
Acre	3.82%	24.2%	0.71	2,195
Amapa	3.30%	20.7%	0.69	2,281
Amazonas	12.53%	22.6%	0.70	1,944
Maranhao	4.82%	27.3%	0.68	1,623
Mato Grosso	1.92%	22.0%	0.74	2,813
Para	2.67%	32.6%	0.69	1,831
Rondonia	1.52%	27.3%	0.70	2,293
Roraima	15.34%	13.4%	0.70	2,490
Tocantins	2.19%	21.3%	0.73	2,364

The **Amazonas** and **Roraima** states have the highest share of minority groups, which include indigenous and Quilombola people.

A combination of factors like **poor infrastructure** and **economic structure** are driving this disparity.

Source: National Census, IBGE, 2022.

Brazil's electrification efforts to date

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Brazil is close to reaching universal electricity access thanks to effective policies for rural electrification.

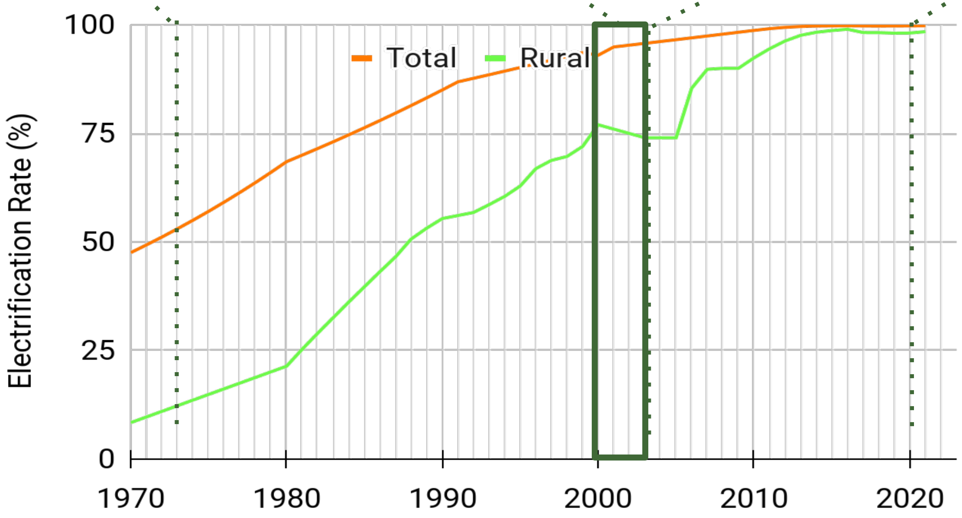
- Last mile users located in the northeastern territories continue to face challenges.
- Government programs focus on extending electricity access and replacing diesel generators with decentralized small-scale generation.

1973: Conta de Consumo de Combustíveis (CCC)

2000-03: Blackout crisis and failed policy

2003: Luz para Todos

2020: Mais Luz para a Amazônia



- 1973 the **Conta de Consumo de Combustíveis (CCC)** program subsidizes the purchase of fuels used in electricity generation for isolated systems, and it remains in effect to this day.
- In the early 2000's the **Luz no Campo** program targeted electricity access to 1 million people by providing loans to finance installations. The program failed due to high costs; meanwhile, the electricity system was hit by a major **blackout crisis** caused by a prolonged period of drought and unmet electricity demand.
- In 2003, **Luz para Todos (LPT)** contributed to the steep recovery by promoting renewable energy solutions to meet electrification goals, especially in hard-to-reach areas.
- Since 2020, the **Mais Luz para a Amazônia (MLA)** program focuses on reaching last-mile users in the Amazon region, to not only have access to electricity, but also promote socio-economic development.
- In August 2023, MLA was integrated into LPT

Program spotlight: Luz Para Todos (Light for All)

Who	MME, ENBPar, State govts & local utilities
What	Electrify ~10M rural & low-income people
Where	Rural and remote areas, including the Amazon region, the Northeast, and other underserved regions
When	2003 - 2026 (rural areas) and 2028 (Amazon)
Funding	CDE cross-subsidy, a sector charge paid by consumers of Brazil
Technology	Grid extension (primarily) & standalone systems
Tariff / Subsidy Details	CDE covers CAPEX and part of OPEX; Users pay monthly fee based on social tariff

Successful Outcomes

Achieved 3.76 million connections. Successful elements include…

- **Broad reach and high feasibility** was enabled by combining funding & resources from the public & private sector and national & regional institutions.
- Between 2003 and 2024, LPT has created **3.76 million connections**, **with 17.65 million people benefiting** in rural areas and remote regions of the Amazon. During this period, USD 4.4 billion was invested.
- **In 2023 alone, 64,500 families benefited from the programme** with investments of R$1.4 billion. The Northern region accounted for 43,000 connections, between rural locations and the Amazon.
- **In 2024, 60,200 families benefited** (49,200 in Northern region), through R$1.7 billion investment.

Challenges

- **Sustainability of Past Connections:** There is uncertainty regarding whether the people who gained access to electricity over the last two decades still have stable and reliable access.
- **Monitoring and Maintenance**: Ensuring long-term functionality of installed systems, especially in isolated areas, is challenging. Often, systems lack proper maintenance mechanisms, leading to premature technical failures.
- **Economic Feasibility**: Isolated regions, especially small communities, are not economically viable for typical market-based energy provision models, thus requiring subsidies and tailored solutions.

*see Annex X for summary of other key programs and initiatives

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Program spotlight:
Mais Luz para Amazônia (More Light for the Amazon)

Who	MME
What	Program to provide reliable electricity access to 219,221 households in the Amazon, as well as local schools, health posts, and water wells
Where	Amazon
When	Initially 2020-2022; later projects were incorporated in the LpT program
Funding	Subsidies (including CDE cross-subsidy) and contributions from various electricity sector agents
Technology	RE, primarily PV with storage; includes standalone systems and mini grids up to 100 kWp
Tariff / Subsidy Details	CDE covers CAPEX and part of OPEX; Users pay monthly fee based on social tariff

Positive Elements

- **Provision of electricity interlinked** with other development activities in education, healthcare, and water/sanitation
- **CDE subsidy** and social tariff
- Projects must **comply** with environmental constraints, community engagement and overall sustainability.
- **Partnership** with regional electricity distribution companies to meet technical and operational standards
- **Displacement of small diesel or gasoline generators** currently used by many families in remote areas
- **Backing of a robust legal and regulatory framework**, including support from ANEEL

Challenges

- **Little involvement from communities in O&M:** as seen also in PRODEEM, little involvement from communities on the basic maintenance of solar systems resulted in many faulty systems.
- Currently has its **focus mostly on domestic energy, not PUE**, which creates long-term limitations in economic development and ability to pay.
- **Lack of information** regarding unelectrified population and database of installed systems to avoid duplication and monitor progress.

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Future plans and considerations for electrification

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Brazil's electrification goals outlined in the Luz para Todos program are facilitated by a series of complementary policies.

Initiative	Description	Regulator
Social Tariff for Low-Income Consumers	Provides discounts on electricity tariffs for low-income families, ensuring that once households are connected to the grid, energy remains affordable.	National - Law No. 12.212/2010
Energy Auctions for Isolated Systems	Incentivizes the development of renewable energy projects and other solutions to provide electricity to isolated areas that are difficult to connect to the SNI.	National Energy Policy Council (CNPE)
Distributed Generation Policy and Solar Energy	Encompasses several initiatives that promote distributed energy generation, including rural solar power projects.	ANEEL Normative Resolutions
Rural Development Plans	The National Program for Strengthening Family Agriculture (PRONAF) and the Growth Acceleration Program (PAC) include provisions for electrification to support economic development, promoting the use of clean energy to support rural livelihoods.	National
National Policy on Rural Electrification with Renewable Energy	*Energias de Amazônia Pro*gram to reduce the use of diesel in isolated systems. Legislation to boost the role of renewable energy in rural electrification by expanding on existing frameworks and promote further integration of renewable energy solutions to power remote and rural areas.	National - Decree 11.648/2023 National - under development

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To help operationalize these targets, Brazil recently developed a **least-cost geospatial plan** to identify unelectrified areas, and determine appropriate technologies to bring them power

THE OBJECTIVE

Develop a least-cost plan to provide electricity to the population located in the Amazonas, Acre, Pará and Roraima states located in the Amazon region, and achieve 100% electrification by 2030.

THE USE CASE

Support the government of Brazil and relevant partners in implementing the *More Light for the Amazon* program. **Please note:** this plan referenced satellite images to run a model based on a specific set of assumptions (including a specific definition of "unelectrified"); as such, its conclusions may not be directly comparable to those of other electrification analyses. This is also *not a government-endorsed roadmap*, nor was it originated as part of UAC activities. It is presented here for informational purposes only.

Least cost geospatial plan partners

Client — MME

Contracting entity — IDB Inter-American Development Bank

Financing support — Global Energy Alliance for People and Planet GEAPP

Technical partners — MIT; we waya energy; tta Trama TecnoAmbiental; Comillas ICAI; IIT Instituto de Investigación Tecnológica

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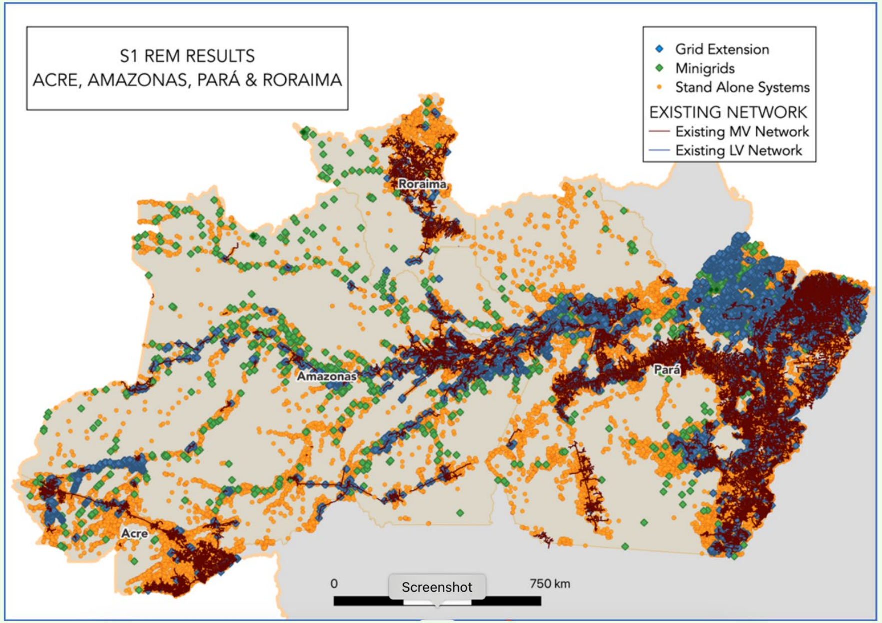
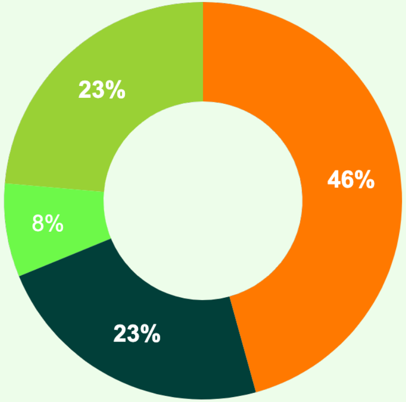
The plan covers a total of 623,711 new clients and an estimated investment of USD 1.34 billion to achieve universal access by 2030.

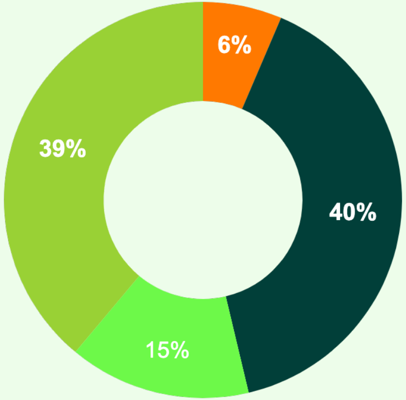


- Densification
- Extension
- Mini grids
- Standalone solar

CONNECTION TYPES



INVESTMENT SHARE



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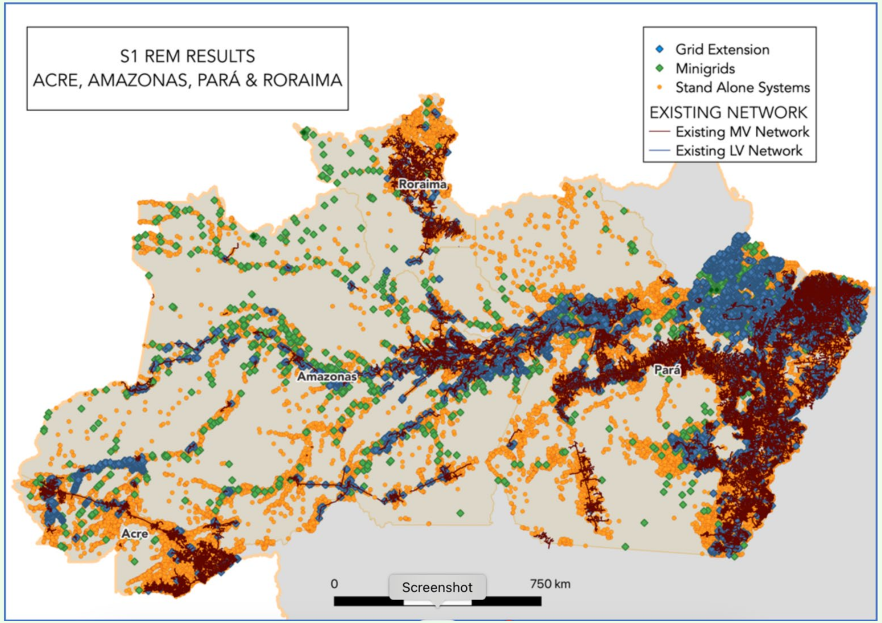
Why the difference between the number of people without electricity access and potential clients?



The variation in the number of people without electricity access presented by the IADB (698,000 people), the MME (990,000 people), and in the number of potential clients presented in the least-cost geospatial plan (623,711 clients) arises from differing scope and methodologies:

- IADB's calculation for electricity access are based on a nationally representative dataset of household surveys.
- MME extends their definition of unelectrified to include customers using isolated diesel generators, as they are not a reliable source of electricity.
- The geospatial plan estimated the number of new clients based on a geospatial analysis that identified the number of people without electricity and added their own projections for population growth until 2030 in only four states (Acre, Amazonas, Pará, and Roraima).

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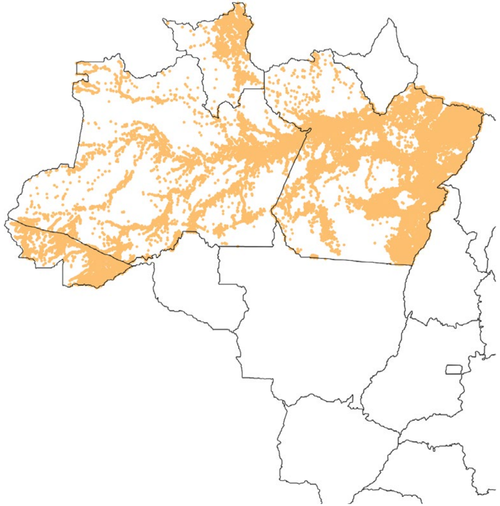
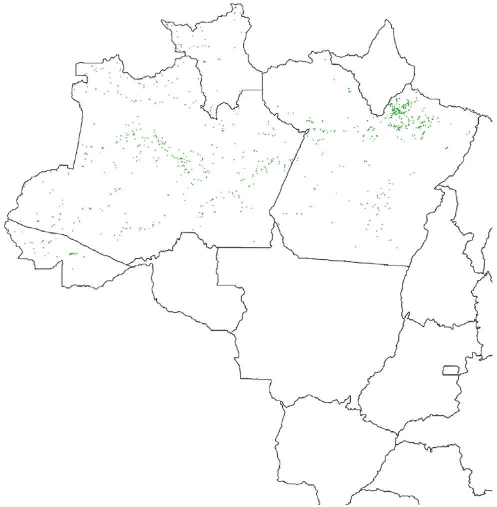
The plan illustrates which least cost electrification technologies are most appropriate for the states of Acre, Amazonas, Roraima, and Pará.

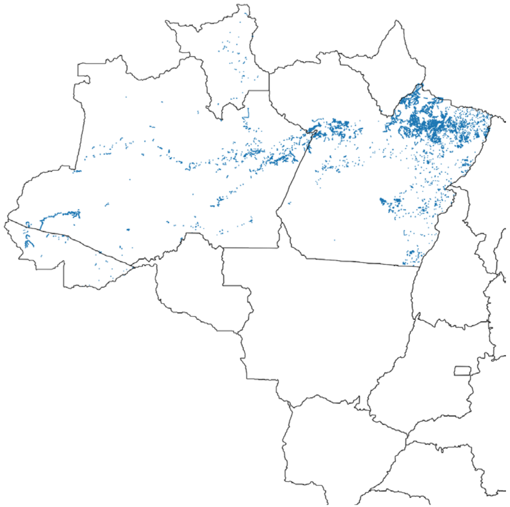
Areas where **standalone solar** is the least-cost option



Areas where **mini-grids** are the least-cost approach



Areas where **grid extension** is the least-cost approach



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Technology 1: Standalone Solar

The plan for dispersed, low-demand households far from the grid

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For standalone solar, the least cost plan shows…

That stand-alone solar systems are the most cost effective solution for electrifying 147,207 households. This represents 23% of the 624 thousand yet to receive first time or improved access to energy through system replacements.

In the scenario presented in the geospatial plan, **USD 522 million is the estimated investment** required to reach this target.

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Key Players: Government Partners for Standalone Solar Projects

Name	Description
MME	The **Ministry of Energy and Mines (Ministério de Minas e Energia - MME)** is the primary government body responsible for the overall energy policy, including those related to rural electrification. The ministry develops policies and regulations for standalone solar, incorporating standalone solar projects into broader national energy plans and strategies. MME also engages with private sector stakeholders to promote the development of standalone solar, facilitating partnerships and collaboration.
INPE	The **National Institute for Space Research (INPE)** is responsible for monitoring and analyzing solar radiation data, a key task for the planning and optimization of solar energy projects. The institute provides data and forecasts that support the design and placement of standalone solar systems.
fnma Fundo Nacional do Meio Ambiente	The **National Fund for the Environment (FNMA)** supports projects related to environmental conservation and sustainable development, including renewable energy projects such as solar PV installations. It provides funding and support for projects that contribute to the transition to the use of clean energy sources.
ANEEL	The **National Electric Power Regulator (Agência Nacional de Energia Elétrica - ANEEL)** is the regulatory body overseeing the electricity sector. ANEEL regulates tariffs and financial incentives for solar energy projects. In addition, ANEEL oversees the quality and reliability of solar energy systems.
BNDES	The **Brazilian Development Bank (Banco Nacional de Desenvolvimento Econômico e Social - BNDES)** is a federal public bank that provides financial support for infrastructure projects, including those related to standalone solar deployment by offering financing options, including low-interest loans and credit lines.
State & Municipal Energy Departments	The **State and Municipal Governments** have their own energy departments or secretariats that are involved in local energy planning and regulation. They play a role in approving and supporting standalone solar energy projects at the regional level by issuing permits, providing local incentives, and supporting the implementation of the projects within their jurisdictions.

Key Players: Development Partners for Standalone Solar Projects

Name	Description
WWF	The **World Wildlife Fund (WWF)** is involved in various environmental and conservation projects, including those focused on sustainable energy. WWF supports solar energy projects as part of their efforts to promote renewable energy and mitigate climate change by implementing the solutions and working with local communities to promote sustainable energy practices.
ENERGY4IMPACT	**Energy4Impact** has been involved in supporting standalone solar projects in Brazil. The organization aims to enhance energy access and support sustainable development by promoting the use of renewable energy technologies. For standalone solar projects, they focus on providing off-grid communities wit reliable and clean energy solutions in isolated regions where extending the national grid is economically or logistically challenging.
The Nature Conservancy	**The Nature Conservancy (TNC)** engage in projects that integrate sustainable energy solutions, including standalone solar projects in Brazil. The projects aim to support conservation efforts by providing renewable energy solutions to remote and ecologically sensitive areas to help reduce reliance on fossil fuels and minimize environmental impacts. TNC collaborates with local NGOs, community organizations and government agencies to implement the solar projects.
Hivos people unlimited	**Hivos** support renewable energy projects in Brazil, including standalone solar systems. Hivos's standalone solar projects are designed to provide reliable, clean energy solutions to remote communities with solar home systems, community solar projects, and solar-powered social enterprises.
UNDP	**UNDP** often works in conjunction with the Global Environment Facility (GEF) to implement projects that focus on renewable energy and climate action. Among the funded projects are solar powered mini-grid and standalone solar deployment in the Amazon to reduce deforestation and improve local livelihoods.

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Key Players: Execution for Standalone Solar Projects

Ownership	Name	Description
Public	MME, Eletrobras, ENBPar (Empresa Brasileira de Participações em Energia Nuclear e Binacional)	The **Luz para Todos** program aims to provide electricity to rural and low-income households across Brazil with mini-grids and standalone solar in areas where grid extension is not viable. This solution targets the remote areas in the Amazon region and northeast of Brazil. In 2023, the LPT was transferred to ENBPar, due to the privatization of Electrobras.
Private	engie	**Engie Brazil's** solar projects focus on providing clean and affordable energy to communities where grid extension is impractical. The projects target remote regions and promotes renewable energy solutions, namely solar PV systems combined with battery storage. Engie's projects focus on community development and promoting socio-economic growth.
	enel	**Enel Brasil** develops and operates solar power plants and standalone solar systems through its subsidiary Enel Green Power who focuses on both large-scale and small-scale projects to address energy access in remote areas. The company has been involved in numerous projects in the Amazon region, providing solar solution to indigenous and remote communities.
	Grupo energisa	**Energisa's** standalone solar projects are designed to enhance energy access in remote areas with solar home systems provided to individual households. These systems typically include solar panels, batteries, and energy-efficient lighting. Energisa has undertaken standalone solar projects in the states of Mato Grosso, Paraíba, and Tocantins.
	SUSTENTARE Energia Solar	**Sustentare** specializes in solar energy solutions aimed at improving energy access in rural areas across Brazil. Their projects focus on rural electrification, solar-powered solutions for agricultural applications, and offering solar home systems and community-based solar projects to meet local energy needs.
	NEOENERGIA	**Grupo Neoenergia** has been active in providing standalone solar solutions to remote areas in Brazil by collaborating with technology providers and financial institutions for facilitate the deployment and financing of solar systems.
	Grupo equatorial Energia	**Equatorial** is a leading private company in Brazil's energy sector, entrusted by ANEEL with the country's most ambitious electrification targets. With a strong commitment to expanding energy access, Equatorial plays a pivotal role in advancing sustainable and inclusive energy solutions.

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Standalone systems: Key Challenges

Logistical

Challenges	Key considerations going forward
• **Remote localities and poor or no road access** led to high transportation cost of installation, challenges when performing O&M, as well as supply chain constraints. All of these factors lead to longer project executing times, as well as prolonged downtimes when system failures occur.	• Connecting the last mile will come at a cost premium, and that **concessional/philanthropic capital will likely be required** to make it happen • Consider these conditions when drafting the **project timeline and budget.**
• **Shortage of trained personnel or technicians** capable of providing maintenance services. Remote areas in the Amazon have lower education levels than other parts of the country, so even training individuals to perform basic technical tasks can be a bigger challenge than in peri-urban areas.	• Compounded by **dispersed populations** (point above). • Consider simpler, more **plug and play solution**s that have limited installation and maintenance requirements

Standalone systems: Key Challenges

Planning

Challenges	Key considerations going forward
• **Lack of information** on the exact number and location of households without electricity hinders planning. Implementation of the Mais Luz para a Amazônia/Luz para Todos program suffers from inefficiencies and potential duplication due to the lack of a database on installed systems. Distribution companies not reporting all installations.	• The **geospatial plan** is an important step forward in understanding location and appropriate technology to connect areas. • **Program design and budget** should be sufficiently **flexible** to adapt to changes in quantity and location of unelectrified households. • Importance of conducting **ground truthing site assessments.**
• **Inefficient processes** wherein DisCos seek government funding to execute projects, yet they also hold auctions, making the process inconsistent and costly.	• The **planning of new projects** should be exclusively the **responsibility of the federal government** to streamline the process. • **Procurement** of solar kits should be coordinated by the federal government and **done in bulk, guaranteeing technical standards and lower costs.** • **DisCos** can acquire the solar kits from one entity and still **execute the installation process.**

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Standalone systems: Key Challenges

Economic & Regulatory

Challenges	Key considerations going forward
• **Market competition:** competing isolated energy sources, like diesel generators, have lower upfront costs because the technology is well established; while standalone systems are a relatively new technology with that require a higher CAPEX, making the option less attractive. Additionally, existing regulations, like the CCC, make the transition to renewable energy systems even less attractive.	• The **cost competitiveness of standalone systems can improve** through technological advancements and bulk purchasing of components. • There can also be a **revision of current subsidy scheme** to target renewable energy isolated systems, instead of power generation with diesel.
• When standalone solar systems are provided as donations by external organizations, recipients may not **fully appreciate the value of the systems**, which can lead to inadequate maintenance and care.	• A **minimum payment** should be made for each connection to ensure the user is inclined to take care of the investment. • All of the installed systems should have a **monitoring system in place** that keeps track of down time and failures, to ensure maintenance is up to date.
• **Reduced tax collection** from diesel commercialization through the ICMS (Imposto sobre Circulação de Mercadorias e Serviços), which is the value added tax on goods and services. The state governments' potential loss of tax revenues generates a pushback towards RE solutions.	• Introduce **other sources of revenue** that can make up for the losses from reduced diesel commercialization.

Standalone systems: Key Challenges

Community Engagement & Education

Challenges	Key considerations going forward
• **Lack of involvement of local communities** in all stages of the projects, from planning, to implementation, and maintenance. This can have similar outcomes to the PRODEEM program, where little involvement from communities on the basic maintenance of solar systems resulted in many faulty systems.	• Ensure **early and continuous involvement of local communities** in program design and implementation, including decision-making, enabling a level of local ownership and trust critical to sustainability. • Implement **information sessions** to demonstrate the benefits of isolated RE systems.
• **Community resistance and distrust** of outsiders and unfamiliarity with new technologies. Given Brazil's vast diversity, language and cultural differences can also play a role in creating misalignment in messaging and creating resistance or distrust.	• Establishing genuine, **long-term relationships with community members** and leaders is key. • Ensure **engagement with community ambassadors** to gain project buy-in and include communities in broader power planning
• **Lack of technical training in communities** can lead to maintenance issues such as users replacing LEDs with inefficient lighting, significantly reducing system capacities	• **Programs need to budget and plan** for training of trainer activities to develop local installation and maintenance expertise and consider providing simplified maintenance guides to support local technicians.

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Standalone solar: Funding Needs

USD 522 million in investment will be required to support reaching universal access by 2030.[1,2]

- Investment per user is an average of about USD 3,500.
- Total annual service cost per user is around USD 1,100/year.

Funding Sources[3]

Government

- 90% of funding from state energy budget.
- USD 800 - 900 million budget for 2025.

Distributors:

- 10% of funding from DisCos private capital.

International Stakeholders: WWF, UNDP, The Nature Conservancy, Hivos, Energy4Impact

(1) Brazil Optimal Georeferenced Plan facilitate Universal Access to Electricity, 2023. (2) Indicative costing is based on the reference scenario in the least cost plan, and makes several assumptions regarding the number and cost of connections. It is subject to revision based on adjusted scenarios and market price discovery. (3) Interviews with coalition partners

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Technology 2: Mini-grids

The plan for clustered households far from the grid

For mini-grids, the least cost plan shows…

That mini-grids are the least cost solution for electrifying **47,492** households. This represents **8%** of the 624 thousand yet to receive access to energy. The size of the communities that would benefit are between 25 and 75 users.

In the scenario presented in the geospatial plan, **USD 198 million** is the estimated investment required to build **1,117 mini-grids** in order to reach this target.

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Key Players: Government Partners for Mini-Grid Projects

Name	Description
MME	The **Ministry of Energy and Mines (Ministério de Minas e Energia - MME)** is the primary government body responsible for the overall energy policy, including those related to mini-grids and rural electrification. The ministry develops policies and regulations for mini-grids, incorporating mini-grid projects into broader national energy plans and strategies. MME also engages with private sector stakeholders to promote the development of mini-grids, facilitating partnerships and collaboration.
INCRA	The **National Institute for Colonization and Agrarian Reform (INCRA)** oversees land reform and rural development. It facilitates access to land necessary for the placement of infrastructure like generation units, transmission lines, and distribution systems. INCRA also supports community engagement efforts and facilitating their participation in mini-grid projects.
FUNAI	The **National Indian Foundation (FUNAI)** protects indigenous land rights and collaborates with project developers to design energy solutions that are sustainable and culturally appropriate for indigenous communities. The organization facilitates community consultations, and supports in monitoring and enforcing compliance with environmental and social safeguards during the planning and implementation of mini-grid projects.
ANEEL	The **National Electric Power Regulator (Agência Nacional de Energia Elétrica - ANEEL)** is the regulatory body overseeing the electricity sector. ANEEL regulates electricity tariffs for mini-grid projects, ensuring affordability and often implementing subsidies and incentives. In addition, ANEEL ensures that mini-grid projects meet performance criteria.
BNDES	The **Brazilian Development Bank (Banco Nacional de Desenvolvimento Econômico e Social - BNDES)** is a federal public bank that provides financial support for infrastructure projects, including those related to mini-grid deployment.
Ministério do Meio Ambiente e Mudança do Clima / Governo Federal Brasil União e Reconstrução	The **Ministry of the Environment (MMA)** ensures that mini-grid projects are sustainable, especially in sensitive ecosystems such as the Amazon rainforest. Through its environmental agencies (such as IBAMA), the ministry issues environmental licences while promoting the integration of renewable energy in mini-grid projects.

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Key Players: Development Partners for Mini-Grid Projects

Name	Description
WORLD BANK GROUP	The **World Bank** has been a major financier and technical advisor for energy projects in Brazil, including those involving mini-grids. The Energy Sector Management Assistance Program (ESMAP) is a key program that provides technical support and financial assistance for the development of mini-grid projects. Additional funding support comes through concessional loans and private sector investment via the International Finance Corporation (IFC).
IDB Inter-American Development Bank	The **IDB** has been actively involved in financing and promoting sustainable energy projects in Brazil, including mini-grids. The IDB supports projects that aim to increase access to electricity in rural areas while promoting the use of renewable energy sources. Moreover, it has provided loans and grants for rural electrification projects that incorporate mini-grid solutions, supported technical studies and pilot projects for renewable energy-based mini-grids, and worked with the Brazilian government to develop policies and frameworks that encourage private sector participation in mini-grid development.
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH	**GIZ** has been a key partner in promoting renewable energy and sustainable development in Brazil. GIZ's work includes supporting mini-grid projects, particularly those that use renewable energy sources. It has provided technical assistance and capacity-building support for mini-grid projects, focusing on renewable energy integration, facilitated knowledge exchange and best practices in mini-grid development through workshops and training programs.
AFD AGENCE FRANÇAISE DE DÉVELOPPEMENT	The **French Development Agency (AFD)** supports energy access projects, including min-grids, by providing financing and technical assistance, often in collaboration with the EU and other international partners.
UNDP	**UNDP** often works in conjunction with the Global Environment Facility (GEF) to implement projects that focus on renewable energy and climate action. Among the funded projects are solar powered mini-grid deployment in the Amazon to reduce deforestation and improve local livelihoods.
European Union	The **EU** has supported several energy projects in Brazil, with a focus on promoting renewable energy and sustainable development. It's involvement often includes support for mini-grid projects in rural areas. It has provided grants and technical support for renewable energy-based mini-grids in underserved communities, supported the development of policies and frameworks that encourage investment in mini-grids and promoted capacity-building initiatives to ensure the long-term sustainability.

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Key Players: Execution for Mini-Grid Projects

Ownership	Name	Description
Public	MME, Eletrobras, ENBPar (Empresa Brasileira de Participações em Energia Nuclear e Binacional)	The **Luz para Todos** program aims to provide electricity to rural and low-income households across Brazil with mini-grids and standalone solar in areas where grid extension is not viable. This solution targets the remote areas in the Amazon region and northeast of Brazil. In 2023, the LPT was transferred to ENBPar, due to the privatization of Electrobras.
	ANEEL	**Projeto Piloto - Solar Mini-Grids in Amazonia** is a pilot project funded by ANEEL that focuses on developing solar-powered mini-grids in remote communities in the Amazon region. The aim is to replace costly and polluting diesel generators with clean and renewable energy.
Private	engie	**Engie Brazil's Solar Mini-Grids** focus on providing clean and affordable energy to communities where grid extension is impractical. The project targets remote regions and promotes renewable energy solutions, namely solar PV systems combined with battery storage. Engie's projects focus on community development and promoting socio-economic growth.
	edp	**EDP Brazil's Hybid Systems in Isolated Areas** has deployed hybrid mini-grids in remote areas, combining renewable sources with backup generators to ensure consistent power where extending main grid is not feasible.
	voltalia	**Voltalia** is a renewable energy company that has been involved in several mini-grid projects in Brazil, with strong emphasis on solar energy. Voltalia's mini-grids are primarily solar-based with energy storage systems, and have mostly been deployed in the northeast of Brazil.
	Omega energia	**Omega Energia** is a Brazilian renewable energy company utilizing renewable energy sources to develop decentralized energy systems that are critical for rural electrification. Omega focuses on bringing electricity to remote and isolated regions of Brazil, especially in the Amazon.
	Grupo equatorial Energia	**Equatorial** is a leading private company in Brazil's energy sector, entrusted by ANEEL with the country's most ambitious electrification targets. With a strong commitment to expanding energy access, Equatorial plays a pivotal role in advancing sustainable and inclusive energy solutions.

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Mini-Grids: Past Challenges

Planning & Operational

Challenges	Key considerations going forward
• **Lack of data and mapping communities:** There is lack of data regarding the exact number of unelectrified population and little data on installed systems. In addition, populations in remote regions often migrate, posing an added challenge when identifying a precise number and location of the population. This can lead to duplication in electrification efforts and added challenges when monitor the progress of projects.	• **Reinforce local engagement** by strengthening relationships with local organizations, and coordinate efforts between different institutions to build a centralized database. Organizations like FUNAI can help coordinate efforts. • **Use new technologies like remote sensing and satellite data** to estimate population density and distribution of off-grid areas.
• **Logistical Difficulties**: Maintaining mini-grids in remote areas presents significant challenges due to logistical issues, such as access to spare parts and the availability of technical expertise. The long maturation time of these projects, coupled with the need for ongoing support and maintenance adds to the operational complexity and costs, particularly in isolated regions like the Amazon.	• Start to **build supply chain and logistic networks,** anchored around existing associations that already have the expertise in reaching isolated regions.

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Mini-Grids: Past Challenges

Economic

Challenges	Key considerations going forward
● **Limited Focus on PUE:** Infrastructure planning is heavily focused on domestic use, while productive use of energy, which drives mini-grid profitability and economic growth, remains underdeveloped. Most mini-grids are single-phase, limiting their capacity to support business models that require higher energy consumption, and thereby limiting the users' ability to pay for the service.	● Consider **infrastructure upgrades to support PUE** when planning mini-grid projects, like increasing the electricity output. ● **Incorporate productive uses into planning** to stimulate economic growth and enhance the value of projects. ● Explore the **development of mini-grids that support higher energy consumption needs**, enabling diverse business models and economic activities.

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Mini-Grids: Past Challenges

Cultural and Regulatory

Challenges	Key considerations going forward
• **Local cultural dynamics**: Brazil has a large diversity of socioeconomic and cultural contexts. Local dynamics and social structures can affect the implementation of projects and their acceptance. Misaligned expectations or lack of involvement can lead to failure of the project.	• **Ensuring community buy-in and participation** is essential for the success of mini-grid projects, and the requirements for buy-in can be highly context-specific. • **Maintaining clear and open communication** with all involved parties facilitates transparency and confidence in the project, building spaces where any issues can be addressed.
• **Lack of Awareness and Training**: Cultural and educational barriers in rural populations, such as the lack of knowledge about new technologies, distrust of external actors, and low levels of education have created additional challenges in implementation.	• It is important to **understand and respect local customs and social structures** before moving forward with informative and education sessions.
• **Permits:** because the Amazon is a protected ecosystem, there is a meticulous permit process that has to be completed before executing any project, including community consultations, environmental permits, and sanitary protocols, to name a few. This process can delay projects significantly.	• **Performing comprehensive and detailed feasibility studies** at the beginning of projects can anticipate any bottlenecks and help plan accordingly. • **Building partnerships with local entities** can help facilitate understanding of local requirements and enhance credibility in the permitting process.

Mini-grids: Funding Needs

USD 198 million in investment is required to support reaching universal access by 2030.[1,2]

- Investment per user ranges from USD 4,100 to USD 4,400/connection.
- Total annual service cost per user is around USD 800/year.

Funding Sources[3]

Government

- 90% of funding from state energy budget.
- USD 800 - 900 million budget for 2025.

Distributors:

- 10% of funding from DisCos private capital.

International Stakeholders: WB, IDB, GIZ, AFD, UNDP, EU

Sources: (1) Brazil Optimal Georeferenced Plan facilitate Universal Access to Electricity, 2023. (2) Indicative costing is based on the reference scenario in the least cost plan, and makes several assumptions regarding the number and cost of connections. It is subject to revision based on adjusted scenarios and market price discovery. (3) Interviews with coalition partners

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Technology 3: Grid Extension

The plan for households near enough to the grid to justify investment in distribution infrastructure

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For grid extension, the least cost plan shows…

That grid extension are the least cost solution for electrifying **143,847** households. This represents **23%** of the 624,000 yet to receive access to energy.

In the scenario presented in the geospatial plan, **USD 535 million** is the estimated investment required to provide 3,000 extensions in order to reach this target.

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Key Players: Government Partners for Grid Extension

Name	Description
MME	The **Ministry of Energy and Mines (Ministério de Minas e Energia - MME)** is the primary government body responsible for the overall energy policy, including electricity generation, transmission, and distribution. It oversees the implementation of energy policies, regulates tariffs, and ensures the expansion of the grid aligns with public interest.
ANEEL	The **National Electric Power Regulator (Agência Nacional de Energia Elétrica - ANEEL)** is the regulatory body overseeing the electricity sector. It ensures that energy providers comply with regulations and standards, and facilitates the implementation of policies related to grid expansion and densification.
ONS Operador Nacional do Sistema Elétrico	The **National System Operator (Operador Nacional do Sistema Elétrico - ONS)** is the national grid system operator that works closely with government bodies to ensure the integration of grid expansion plans and operational efficiency across the national electrical system.
BNDES	The **Brazilian Development Bank (Banco Nacional de Desenvolvimento Econômico e Social - BNDES)** is a federal public bank that provides financial support for infrastructure projects, including those related to grid extension to remote areas.
ccee	The **Chamber or Electric Energy Commercialization (Câmara de Comercialização de Energia Elétrica - CCEE)** manages electricity trading in Brazil, it plays a role in the commercialization of new grid-connected areas and helps stabilize the electricity market.
IBAMA MMA	The **Brazilian Institute of Environment and Renewable Natural Resources (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - IBAMA)** ensures the environmental regulations are met during the construction of infrastructure associated with grid expansion.
State & Local Governments	**State and local governments** in Brazil also have a role in coordinating and implementing grid expansion projects, especially in rural and remote areas. They have energy departments that coordinate with federal initiatives on grid expansion, tailoring national programs to regional needs.

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Key Players: Development Partners for Grid Extension

Name	Description
WORLD BANK GROUP	The **World Bank** has been a significant partner in Brazil's efforts to expand and densify its electrical grid. Through various projects, it has provided loans and technical assistance for rural electrification and infrastructure development aimed at increasing access to electricity in underserved areas
IDB Inter-American Development Bank	The **Inter-American Development Bank (IDB)** has supported numerous energy projects in Brazil. The bank provides both financial resources and technical support for infrastructure projects that contribute to grid extension.
UNDP	The **United Nations Development Program (UNDP)** has collaborated with Brazil on sustainable energy solutions and rural electrification projects. It has helped promote policy and partnerships that integrate renewable energy into grid extension programs.
USAID FROM THE AMERICAN PEOPLE	The **United States Agency for International Development (USAID)** has supported energy programs in Brazil, particularly those focused on improving energy access by fostering an enabling environment for investments, promoting off-grid renewable solutions, and improving policy frameworks.
European Union	The **European Union** has supported Brazil's grid densification efforts through channels like financial assistance, technical support, and policy dialogue. Various technical cooperation programs support Brazil's grid modernization and densification projects, while EU Investment and Development Funds and the European Investment Bank (EIB) provide financial support. The EU-Brazil Energy Cooperation facilitates bilateral dialogues focusing on energy policy related to grid densification, expansion, and modernization.
giz KFW	The **German Development Cooperation (GIZ)** provides technical assistance and capacity building on clean energy and grid expansion projects. In parallel, the **KfW Development Bank** is involved in financing grid expansion projects in Brazil, focusing on integrating clean energy into the grid and improving access to electricity in remote areas.

Key Players: Execution for Grid Extension Projects

Ownership	Name	Description
Public	MME, Eletrobras, ENBPar	The **Luz para Todos** program aims to provide electricity to rural and low-income households across Brazil by extending the existing power grid. State and local governments work together to build new infrastructure in priority areas, including rural agricultural areas, indigenous communities and arias with significant poverty rates. Between 2003 - 2021 the program has provided electricity to over 16 million people. In 2023, the LPT was transferred to ENBPar, due to the privatization of Electrobras. **Mais Luz para Amazônia** focuses on extending the electricity grid to remote areas in the Amazon, where its remote nature has made electrification difficult.
Private	edp	**EDP** has been actively involved in connecting rural communities to the national grid in the regions it serves, helping fulfill the Luz Para Todos program though the construction of new transmission lines, and the integration of renewable energy solutions to serve isolated rural communities.
	enel	**Enel Brasil** has actively served the states of Ceará and Goiás in grid extension efforts to reach remote, rural populations by targeting investments and the use of advanced technologies. In addition to grid extension, Enel's transmission projects help address bottlenecks in the national grid, ensuring electricity can be efficiently transmitted to demand centers, including rural regions.
	ENGIE	**Engie Brasil** has developed transmission line projects to connect its power generation facilities to the national grid, for example to integrate power from wind farms in Brazil's northeastern states to the national transmission grid. The company facilitated the extension of the grid to nearby communities, providing them with access to electricity as well as supported the integration of renewable energy sources by strengthening grid infrastructure.
	Grupo Energisa	**Energisa**, a major electricity distribution company, is already serving 862 municipalities in Brazil, reaching about 20 million people across 97% of the territory. Energisa is actively working to improve the quality of the electricity network, as well as expand it. The company has recently received funding for extending the distribution network in the states of Acre, Mato Grosso, Mato Grosso du Sul, Minas Gerais, Paraíba, Rondônia, Sergipe, Minas Gerais, Paraná, and Tocantins.
	Grupo Equatorial Energia	**Equatorial** is a leading private company in Brazil's energy sector, entrusted by ANEEL with the country's most ambitious electrification targets. The company has distribution networks in seven states, and over 3,000 Km of transmission lines.

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Grid Extension: Key Challenges

Geographic

Challenges	Key considerations going forward
• **Complex Terrain:** Brazil's Amazon is predominantly covered with rainforest, known for its humid climate, dense vegetation, extensive network of waterways, and rich biodiversity, posing a challenge for building any type of extensive infrastructure.	• Where terrain is demanding but grid extension continue to be the least cost technology, cost savings could be gained by **deploying modular or prefabricated components to construction areas,** which are easier to transport and assemble in difficult terrain.
• **Low population density**: about half of Brazil's unelectrified population are in remote regions of the Amazon. Population density in these regions average about 6.5 persons per km^2, and can be as low as 2.5 persons per km^2, creating significant challenges to developing profitable business models.	• Create **strategic plans for phased grid expansion** that focus on gradually connecting closer population centers while supporting remote areas with off-grid solutions, preferably mini-grid or AC PV systems which could integrate in the future once the grid arrives.

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Grid Extension: Key Challenges

Technical & Operational

Challenges	Key considerations going forward
• **Operation and Maintenance:** Other implementing agents (like NGOs) are executing projects in concession areas belonging to DisCos without previous coordination. Once the project is complete, it is the DisCos' responsibility to upkeep the equipment, which can at times be incompatible with the existing connections.	• **Establish clear requirements and procedures** for executing electrification projects and ensure that all key players involved are informed and aligned. • **Establish decentralized maintenance hubs** that service a cluster of grid extension who are more familiar with the local projects and can be more readily available at the time of executing projects to ensure technical compatibility.
• **Sustainability of past connections and monitoring maintenance**: There is uncertainty if people who have gained access to electricity still have stable and reliable service. Often, systems are installed without proper mechanisms for maintenance, leading to degradation overtime.	• **Remote monitoring and smart grid technology** can feed the necessary **information** to determine the reliability of grid extension. • **Scheduled preventative maintenance** with routine inspections and preventative maintenance practices can extend the life of projects.
• **Skilled Personnel Shortage**: Shortage of technicians in rural areas who can perform necessary maintenance and repairs, leading to longer downtimes and reduced service quality.	• **Establish training programs and incentives** to attract and retain skilled technicians in rural areas, reducing downtime and improving service quality.

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Grid Extension: Key Challenges

Economic

Challenges	Key considerations going forward
• **Economic feasibility:** Isolated communities are not economically viable for market-based provision models.	• **Consider hybrid financing models** with public-private partnerships (PPP) or blended finance that can help reduce the burden on the public sector. PPPs can leverage the expertise and efficiency of the private sector while utilizing government incentives or guarantees, while blended finance can reduce the risk and make projects more attractive to private investors.

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Grid Extension: Key Challenges

Regulatory & Institutional

Challenges	Key considerations going forward
• **Distribution companies undergoing privatization**: All seven government-owned distribution companies were privatized between 2016 and 2018, and Eletrobras was privatized in 2022. Private companies' prioritization of profit has contributed to neglect of last-mile regions.	• **Strong regulatory frameworks** can ensure private companies serve all areas, including remote ones. It is important to find the balance between profitability and social obligations.
• **Regulatory Challenges**: The regulatory system includes federal, state, and municipal regulations that can vary widely and conflict with one another. Navigating the complex requirements and securing the necessary project approvals can require specialized expertise, causing significant delays and increasing costs.	• **Streamline the permit process** by potentially gathering all of the relevant information in one platform and clearly identifying the regulatory body for each step. • **Address redundancies, conflicts, and discrepancies** across the network of regulations.

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Grid Extension: Funding Needs

USD 535 million in investment is required to support reaching universal access by 2030.[1,2]

- Investment per user ranges from USD 1,635 to USD 5,575.
- The total cost of service (CAPEX+OPEX) per user ranges from USD 330 to USD 855 per year.

Funding Sources[3]

Government

- 90% of funding from state energy budget.
- USD 800 - 900 million budget for 2025.

Distributors:

- 10% of funding from DisCos private capital.

International Stakeholders: WB, IDB, UNDP, USAID, EU, KfW

Sources: (1) Brazil Optimal Georeferenced Plan facilitate Universal Access to Electricity, 2023. (2) Indicative costing is based on the reference scenario in the least cost plan, and makes several assumptions regarding the number and cost of connections. It is subject to revision based on adjusted scenarios and market price discovery. (3) Interviews with coalition partners

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Technology 4: Grid Densification

The plan for households that are currently very near or under the grid, primarily in highly populated areas

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For grid densification, the least cost plan shows…

That grid densification is the least cost solution for electrifying **285,165** households. This represents **46%** of the nearly 624 thousand new connections.

In the scenario presented in the geospatial plan, **USD 86 million** is the estimated investment required to reach this target.

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Key Players: Government Partners for Grid Densification

Name	Description
MME	The **Ministry of Energy and Mines (Ministério de Minas e Energia - MME)** is the primary government body responsible for the overall energy policy, including electricity generation, transmission, and distribution. It plays a central role in planning and implementing grid densification projects.
ANEEL	The **National Electric Power Regulator (Agência Nacional de Energia Elétrica - ANEEL)** is the regulatory body overseeing the electricity sector. It ensures that energy providers comply with regulations and standards, and facilitates the implementation of policies related to grid expansion and densification.
ONS Operador Nacional do Sistema Elétrico	The **National System Operator (Operador Nacional do Sistema Elétrico - ONS)** is the national grid system operator that works closely with government bodies to ensure the integration of grid expansion plans and operational efficiency across the national electrical system.
BNDES	The **Brazilian Development Bank (Banco Nacional de Desenvolvimento Econômico e Social - BNDES)** is a federal public bank that provides financial support for infrastructure projects, including those related to grid densification and energy infrastructure development.
State & Local Governments	State and local governments in Brazil also have a role in coordinating and implementing grid densification projects, especially in rural and remote areas. They often work in collaboration with national agencies like MME and ANEEL.

Key Players: Development Partners for Grid Densification

Name	Description
WORLD BANK GROUP	The **World Bank** has been a significant partner in Brazil's efforts to expand and densify its electrical grid. Through various projects, it has provided loans and technical assistance for rural electrification and infrastructure development aimed at increasing access to electricity in underserved areas
IDB Inter-American Development Bank	The **Inter-American Development Bank (IDB)** has supported numerous energy projects in Brazil. The bank provides both financial resources and technical support for infrastructure projects that contribute to grid densification.
CAF DEVELOPMENT BANK OF LATIN AMERICA	The **Development Bank of Latin America (CAF)** provides financing for infrastructure projects that enhance energy access, efficiency, and sustainability; including grid densification projects.
USTDA U.S. TRADE AND DEVELOPMENT AGENCY	The **United States Trade and Development Agency** has provided funding for feasibility studies and technical assistance for grid infrastructure projects in Brazil. Their support also includes capacity-building initiatives and promoting investment opportunities for U.S. companies looking to enter the Brazilian market, or other international investors interested in collaborative projects.
European Union	The **European Union** has supported Brazil's grid densification efforts through channels like financial assistance, technical support, and policy dialogue. Various technical cooperation programs support Brazil's grid modernization and densification projects, while EU Investment and Development Funds and the European Investment Bank (EIB) provide financial support. The EU-Brazil Energy Cooperation facilitates bilateral dialogues focusing on energy policy related to grid densification, expansion, and modernization.
GREEN CLIMATE FUND	The **Green Climate Fund (GCF)** has been involved in funding grid modernization projects in Brazil, with the efforts to reduce greenhouse gas emissions and enhance climate resilience.

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Key Players: Execution Partners for Grid Densification

Ownership	Name	Description
Public	Eletrobras	**Electrobras** is Brazil's largest electric utility company and manages 38.5% of the total transmission lines of the National Interconnected System, summing up to over 73,880 km. The company is involved in several large-scale grid densification and expansion projects that aim to improve connectivity across regions.
	ENBPar	**ENBPar** is a public company founded in 2022, linked to the Ministry of Mines and Energy. It took over certain functions from Electrobras after its privatization.
Private	edp	**edp** is an important player in Brazil's electricity sector, involved in generation, distribution, and commercialization of electricity. Since 2017, edp has built more than 3,770 km of transmission lines.
	engie	**Engie** is Brazil's leading renewable energy company, operating in the generation, marketing, and transmission of electricity. The company has more than 3,800 km of transmission lines in operation and has recently won a 30-year concession to design, construct, operate, and maintain 1,000 km of high-voltage lines in the states of Bahia, Minas Gerais and Espirito Santo.
	Grupo energisa	**Energisa**, a major electricity distribution company, is already serving 862 municipalities in Brazil, reaching about 20 million people across 97% of the territory. Energisa is actively working to improve the quality of the electricity network, as well as expand it. The company has recently received funding for extending the distribution network in the states of Acre, Mato Grosso, Mato Grosso du Sul, Minas Gerais, Paraíba, Rondônia, Sergipe, Minas Gerais, Paraná, and Tocantins.
	enel	**Enel Brasil** is the second largest energy distribution group in Brazil aims to improve its energy distribution grid and quality of service in São Paulo, Rio de Janeiro, and Ceará. The company is planning to invest $2.9 billion between 2024-2026 to strengthen the grid, build new connections, and increase distribution capacity.
	Grupo equatorial Energia	**Equatorial** is a leading private company in Brazil's energy sector, entrusted by ANEEL with the country's most ambitious electrification targets. The company has distribution networks in seven states, and over 3,000 Km of transmission lines.

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Grid Densification: Key Challenges

Technical & Operational

Challenges	Key considerations going forward
• **Aging infrastructure:** Much of Brazil's urban and peri-urban areas have aging grid infrastructure that requires upgrades. This can lead to inefficiencies, outages, and higher losses.	• A **thorough assessment of systems components** is necessary to determine whether they need to be upgraded or replaced during the densification process. Densification projects should consider replacing degraded system components to ensure correct functionality. • Densification efforts should be **aligned with existing maintenance and upgrade plans** for aging infrastructure, thereby minimizing disruptions.
• **Electricity losses:** Electricity theft, particularly in urban and semi-urban areas, remains a challenge for grid operators. Users in densely populated areas tend to connect illegally to the SNI as urban sprawl and electricity demand grows. In 2019, Brazil averaged about 15% of non-technical losses.	• **Improved metering systems coupled with regular audits and inspections** can reduce electricity theft. • **Incorporating smart-grid technology allows for real-time monitoring** of systems, and can help utilities detect areas of high technical losses and take immediate corrections.
• **Integration with Distributed Energy Resources (DER):** Brazil has seen an increase in distributed energy resources, particularly of solar PV systems. Integrating these systems into the existing grid poses operational challenges, including voltage control, reverse power flows, and balancing intermittent renewable generation with demand.	• **Incorporate new, more technologically advanced equipment,** that can help regulate voltage stability, equipment overloads, and manage reverse power flows. • **Energy storage can help stabilize the energy flow** and reduce the need to expand grid infrastructure further.

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Grid Densification: Key Challenges

Policy & Economic

Challenges	Key considerations going forward
• **Long-term planning:** Ensuring grid densification projects are aligned with long-term energy goals is a challenge, especially in rapidly changing energy landscapes as is the case of Brazil.	• Brazil's energy transition towards renewable and distributed energy resources **requires forward-thinking planning,** including forecasting demand growth, incorporating new technologies, and ensuring that the grid remains resilient to future challenges, like climate change.
• **Affordability for low-income consumers:** grid densification projects often target areas with low-income populations, who may struggle to pay for electricity. This creates a financial challenge for utilities, as low revenues from these regions make it difficult to recover the costs of the grid upgrades.	• **Proper tariff structures** are essential to ensure utilities can recover the cost of extending and upgrading the grid. It may be necessary to reform tariffs to account for the unique challenges of grid densification. • **Incorporating DERs** that are able to benefit from net metering schemes can help offset electricity costs for low-income consumers.

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Grid Densification: Funding Needs

USD 86 million in investment is required to support reaching universal access by 2030.[1,2]

- All work and spending to take place exclusively within concessionary zones.

Funding Sources[3]

Government

- 90% of funding from state energy budget.
- USD 800 - 900 million budget for 2025.

Distributors:

- 10% of funding from DisCos private capital.

International Stakeholders: WB, IDB, CAF, USTDA, EU, GCF

Sources: (1) Brazil Optimal Georeferenced Plan facilitate Universal Access to Electricity, 2023. (2) Indicative costing is based on the reference scenario in the least cost plan, and makes several assumptions regarding the number and cost of connections. It is subject to revision based on adjusted scenarios and market price discovery. (3) Interviews with coalition partners