Assessment of Resources for the Universalization of Electrical Energy Access in the Legal Amazon

1. Introduction

This White Paper is designed to catalyze public discourse and mobilize the efforts of the Ministry of Mines and Energy (MME), the National Electric Energy Agency (ANEEL), electricity distribution companies, and other stakeholders t**oward achieving universal electricity access in the remote reaches of the Legal Amazon**. The focus of this white paper is **the identification of the necessary equipment and fiscal resources required** for this objective. This aim, delineated in the Light for All Program – LpT (*Programa Luz para Todos*), intends **to extend the benefits to nearly a million individuals who are still without light**.

The costs projected herein account for the procurement of equipment and the maintenance, operation, and decommissioning services of energy generation and storage systems throughout their operational tenure. The financial resources scrutinized for the sustenance of the LpT are foreseen in the Energy Development Account (CDE), a fiscal subsidization instrument of the State for this public initiative.

The foundational assumptions and methodologies employed in this technical note for the universalization and perpetual maintenance of electrical access are encapsulated in two reports compiled by the *Instituto de Energia e Meio Ambiente – IEMA* (Institute for Energy and the Environment):

- Photovoltaic Systems in the Legal Amazon: Assessment and Policy Proposition for the Universalization of Electrical Energy and Reverse Logistics; and
- Photovoltaic Systems, Costs, and Electro-electronic Waste in the Legal Amazon: An Evaluation of the Light for All Program.

2. The Light for All Program – LpT

Established in 2003, the Light for All Program (LpT) has brought electricity to over 17 million people through the expansion of distribution networks, mainly in rural areas of Brazil (MME, 2023). Despite the program's reach and results, logistical and technical challenges—such as transportation, installation, maintenance, and decommissioning of systems—persist in the Amazon rainforest, contributing to the lack of public access to electricity for nearly a million people in the remote regions of the Legal Amazon.

To overcome this public policy challenge, **in 2020**, **the federal government launched the** National Program for the Universalization of Access and Use of Electricity in the Legal Amazon—**More Light for the Amazon Program – MLA (Programa Mais Luz para a Amazônia)**. **This initiative aimed to serve more than 219,000 consumer units by 2022** that lacked public access to electricity, **exclusively through renewable sources** (MME, 2020). After more than two years, with less than 5% of the goal achieved (IEMA, 2023), in August 2023, the federal government merged the two programs, integrating the premises and guidelines of MLA into LpT (Brazil, 2023).

The program's new goals stipulate ensuring access to electricity for rural consumer units by 2026 and **for more than 226,000 consumer units in the Legal Amazon by**

2028. The decision to prioritize service to consumer units in the Legal Amazon exclusively through renewable sources is a coherent one, aiming to guarantee access to electricity in a sustainable manner.

Public and private entities directly involved in the LpT play fundamental roles in the Brazilian electric sector, with the **MME** coordinating, **Eletrobras** operating, **Distributors and Permit** holders executing, **ANEEL** overseeing regulation, and the Electric Energy Trading Chamber (**CCEE**) managing financial aspects.

Figure 1 outlines the structure and main responsibilities of the entities involved in the LpT.

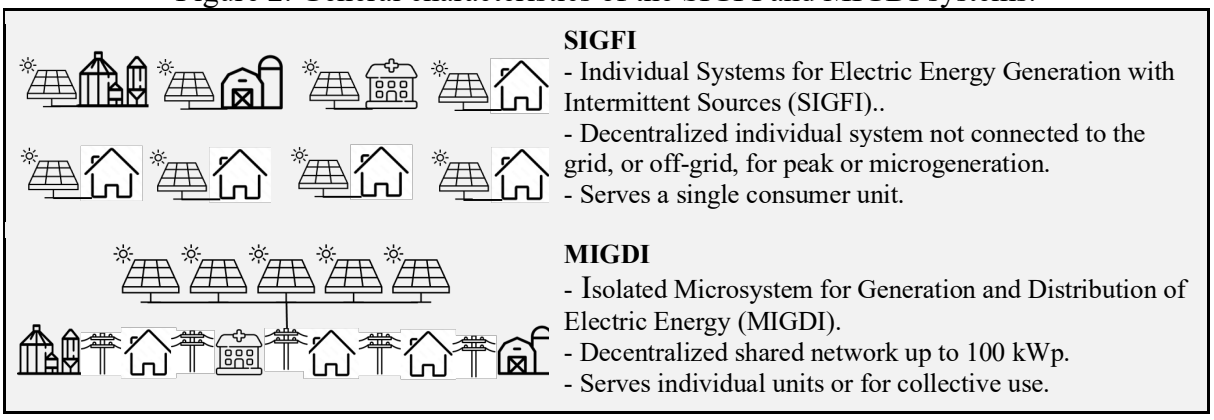
Figure 1. General structure of the LpT Program.

Agente	Principais Atribuições
MME Coordinator	- Coordinate the program and establish its policies and actions. - Define the program's goals and deadlines for each state or concession area. - Approve the operational manual and its revisions and authorize contracts. - Develop and define the renewals of terms, goals, expenses, and the number of new systems.
Eletrobras/ENBPar Operator	- Conduct the technical and budgetary analysis of the work programs authorized by the MME. - Communicate to the CCEE the formalization of contracts to subsidize the release of CDE funds to the executing agent.
Distributor Executor	- Map and record the demands of its concession area. - Implement the systems within their concession regions. - Provide and account for the projects, goals, and execution deadlines of each contract. - Keep the MME's Electric Energy Access Control System (SCAEE) updated.
Aneel Regulator	- Oversee the fulfillment of the goals and deadlines established by the MME. - Send information to the MME to support the definition of goals and deadlines. - Establish the service cost for O&M of the systems.
CCEE Financial Management	- Release CDE funds to executing agents for contract payments. - Send a monthly cash flow report of the program to the MME. - Make available on its website information about the CDE funds transfers to the program.

3. Electricity Supply

The operational manual of the program establishes service criteria with **minimum and maximum thresholds set at 45 kWh and 180 kWh of energy per month for each consumer unit** served by the program (MME, 2020), as detailed in Figure 2.

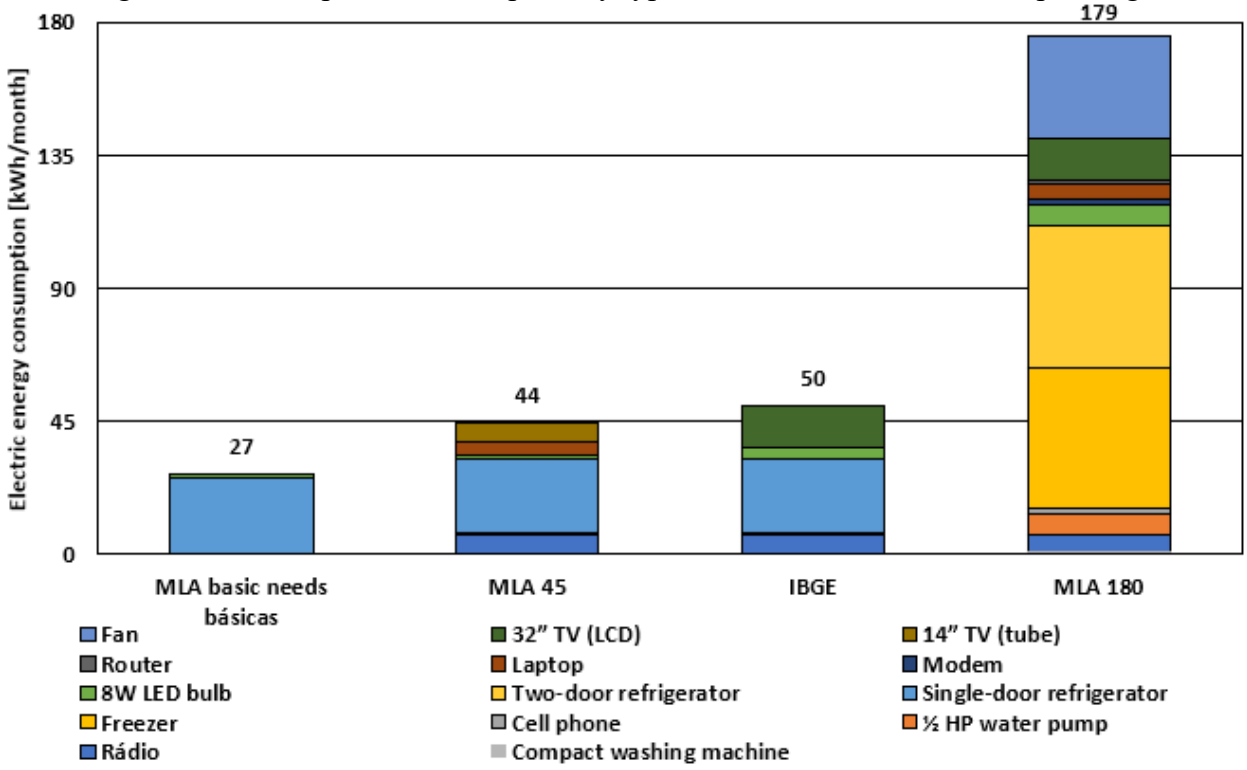
Figure 2. General characteristics of the SIGFI and MIGDI systems.



Depending on the system, **the service only ensures basic needs for lighting, refrigeration, and communication, as with the 45 kWh/month systems. The larger**

systems accommodate some family-level economic activities, as in the case of the 180 kWh/month systems, as depicted in Figure 3.

Figure 3. Electric power consumption by type of service standard of the LpT Program.



The most common arrangement for serving the population is the individual 45kWh/month system (IEI, 2022; IEMA, 2023). This setup aims **to provide the essential minimum electricity to families** while ensuring the transfer of public funds to the utilities executing the program through the social electricity tariff (TSEE).

Within this service bracket, **Quilombola and Indigenous families registered** in the Single Registry (CadÚnico) **are exempt from paying electricity bills**. **Low-income families** are also exempt from some costs of the tariff and receive an **additional discount of 40% on the remaining electricity tariff**.

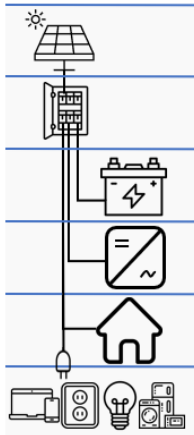
4. Technologies Employed in the LpT Program in the Amazon Region

While the Light for All Program (LpT) is flexible regarding the renewable source used, **the implementation predominantly utilizes off-grid[1] photovoltaic systems linked to an energy storage system through batteries** (IEMA, 2023). **International literature indicates a preference for photovoltaic technology as a solution for serving remote regions with high solar incidence** (IEMA, 2023).

The three main components of this type of system are the photovoltaic module, the battery (lead-acid or lithium-ion), **and the solar inverter**. Figure 4 presents the characteristics of this system.

Figure 4. Basic components of a solar system with energy storage.

[1] Off-grid is a system disconnect from the local utility distribution network.



Photovoltaic Module	A device that generates direct current electricity during daylight from solar rays
Electrical Panel	Controls and ensures the safety of the system: photovoltaic module, battery, consumer unit equipment. Distributes electric energy to the consumer unit.
Battery	A device that stores the direct current energy generated by the photovoltaic modules to be used during nighttime or daytime periods with low sunlight
Solar Inverter	A device that converts the energy generated by the photovoltaic modules or stored in the battery from direct current to alternating current for use in the consumer unit
Consumer Unit	Can be a residence, school, health post, community water well, or community production center..
End Uses	Devices that use electric energy, such as: lamps, refrigerators, freezers, fans, televisions, cell phones, computers.

5. Equipment Quantity to Universalize Access in the Legal Amazon

Between 2020 and 2022, 5% of the goal established in the More Light for the Amazon Program (MLA) was achieved. From 2023 onward, the target will be proportional to the resource allocation of the Light for All Program (LpT)[2], in which **44% of the resources will be released by 2026, and the remaining 56% after 2026** (Casa Civil, 2023).

Table 1 shows the quantity of the three main pieces of equipment per consumer unit required to meet four service scenarios, including the SIGFI standards of 45 kWh/month and 180 kWh/month, with a variation in battery type - lead-acid or lithium-ion.

Table 1. Number of equipment by system type.

Equipment per System		Photovoltaic Module	Battery	Inverter
SIGFI 45	Lead-Acid	4	3	1
	Lithium-Ion	4	1	1
SIGFI 180	Lead-Acid	15	3	1
	Lithium-Ion	15	1	1

Universalizing public access to electricity in the Legal Amazon will require between 3.7 and 15.7 million pieces of solar photovoltaic generation equipment and batteries. Photovoltaic modules are the most required equipment, ranging from 2.2 to 8.4 million units. Lead-acid batteries are the second most demanded equipment for the SIGFI 180 and the most demanded for SIGFI 45, with over 6.5 million units in both cases, as shown in Table 2.

Table 2. Number of equipment by type of system analyzed.

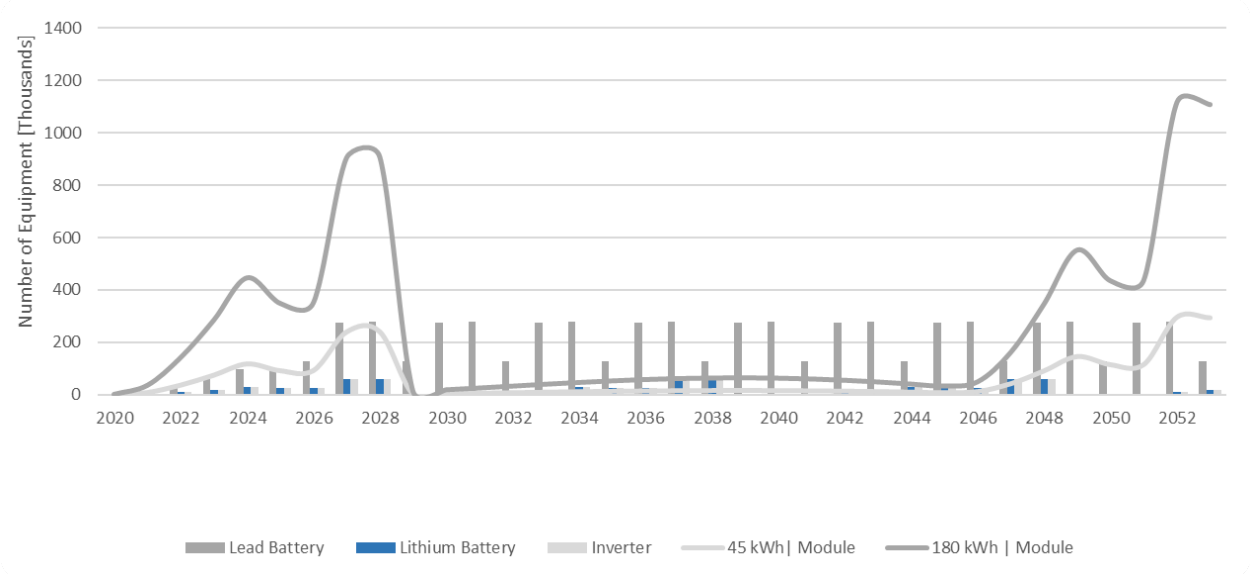
System	Battery Type	Total	Components		Total
SIGFI 45	Lead-Acid	9,489,166	Photovoltaic Module	SIGFI 45	2,241,108
	Lithium-Ion	3,663,508		SIGFI 180	8,404,153

[2] The quantification of the number of equipment necessary for the universalization of electric energy access in the Legal Amazon region is based on the number of systems implemented up to 2022 and the new goals of the LpT Program (IEMA, 2023).

SIGFI 180	Lead-Acid	15,652,211	Inverter	711,200
	Lithium-Ion	9,826,553	Lead-Acid	6,536,858
			Lithium-Ion	711,200

The same quantity of inverters and lithium-ion batteries, exceeding 711,000, is due to the fact that each system is composed of one unit of each, and both have an estimated lifespan of 10 years.
The installation of lead-acid batteries would occur steadily over the years due to their shorter lifespan compared to lithium-ion batteries and other components, making them the second most installed equipment (IEMA, 2023).
Figure 5 illustrates the number of equipment installed annually until the universalization goal is achieved by 2028, including replacements according to the lifespan of each type of equipment.

Figure 5. Temporal distribution of equipment installations.



6. Cost to Universalize Access in the Legal Amazon

Fulfilling the entire Light for All Program (LpT) and **universalizing access to electricity in the Legal Amazon region will require an investment of between BRL 7.2 billion and BRL 38 billion**, as detailed in Table 3.

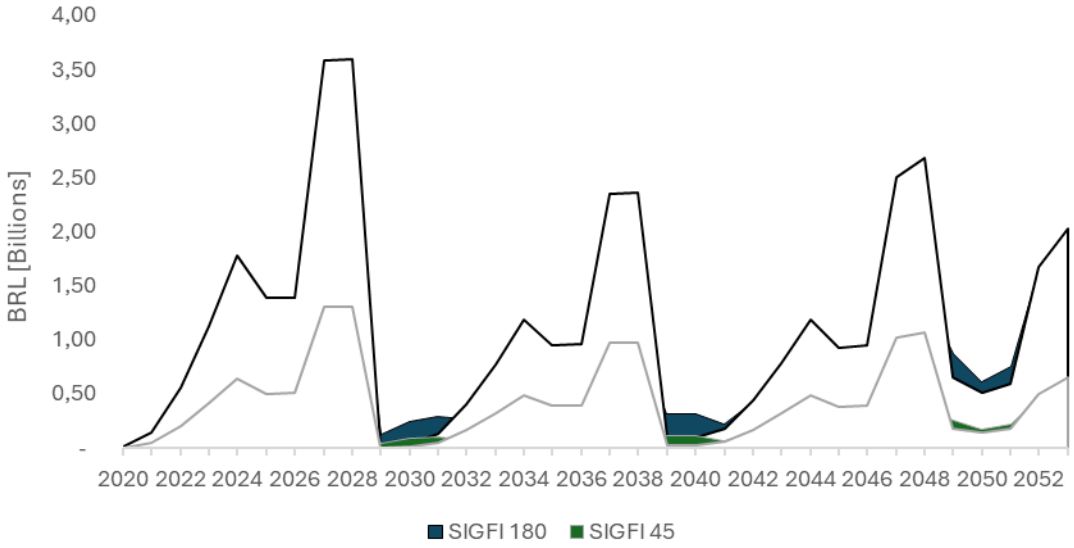
Table 3. Total cost of PV systems.

Custo [R$]	
SIGFI 180 | Lead-Acid Battery	25,182,110,254
SIGFI 180 | Lithium-Ion Battery	38,033,695,294
SIGFI 45 | Lead-Acid attery;	7,205,579,156
SIGFI 45 | Lithium-Ion Battery	14,021,143,890

The estimated average cost of systems per consumer unit is BRL 47,000 for SIGFI 45 kWh/month and BRL 142,000 for SIGFI 180 kWh/month.

Using lithium-ion batteries in SIGFI 180 systems would increase the total cost by almost BRL 13 billion, raising the storage cost by 17%. Although lead-acid batteries have the highest number of units per system, their lower unit cost reduces the total system cost compared to lithium-ion batteries.
Figure 6 details the program costs over time, where the upper limit of the ranges is represented by systems using lead-acid batteries, and the lower limit, by the use of lithium-ion storage systems.

Figure 6. Temporal distribution of program costs.



In the last two years of the universalization target, 2027 and 2028, the greatest cost difference between the systems occurs, amounting to over BRL 2.0 billion. In the period following the universalization target, between 2029-2031 and 2039-2041, the cost difference between SIGFI 45 and SIGFI 180 would average around BRL 89 million.

7. Financial Resources for Public Policies in the Electric Sector

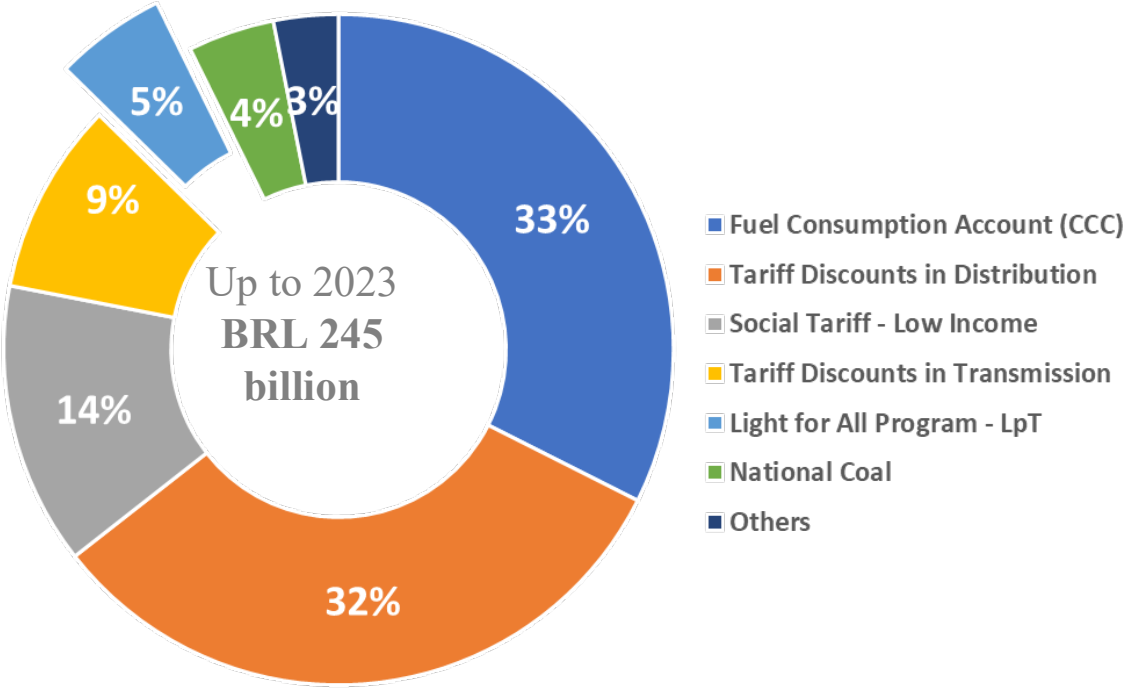
The Energy Development Account (CDE) is a financial mechanism in the Brazilian electric sector, established in 2002 **to fund public policies within the Brazilian electric sector**. It is managed by ANEEL, and its financial resources are handled by the CCEE. Its primary source of funds comes from the collection of sectoral charges included in the tariffs for the use of transmission and distribution, charged on the electricity bill of consumers or collected directly by the CCEE (Brazil, 2021).
The main uses of CDE resources are: covering the fuel account costs (**CCC**), the **universalization** of electricity services, compensation for discounts and **tariff subsidies**, **financial incentives** for alternative sources of renewable energy and polluting sources, and the management of the CDE. A detailed description can be examined in Figure 7.

Figure 7. Main groups of CDE resource allocation.

	Non-Renewable Sources	Ensure the funding of the fuel account (CCC). Promote the competitiveness of energy produced from natural gas and national coal. No source can exceed 30% of the annual CDE collection. Finance the activation of thermal power plants during water scarcity and low levels of hydroelectric reservoirs..
	Subsidies	Subsidize electricity tariffs for indigenous, quilombola, and low-income consumers. Compensar às concessionárias de distribuição, os descontos tarifários concedidos a alguns grupos econômicos. Compensar descontos aplicados nas tarifas de uso dos sistemas elétricos de transmissão e distribuição.
	Universalization of Access	Promote the universalization of electricity services throughout the national territory: - Por extensão da rede de distribuição; ou - Implementação de geração de energia renovável individual ou por minirredes offgrid.
	Renewable Sources	Promote, through financial incentives, the development of alternative energy sources: wind, solar, biomass, and other renewable sources. No source can exceed 30% of the annual CDE collection.
	CDE Management	Provide resources for payments related to the administration and movement of the CDE, administrative and financial costs, and tax charges

From 2013[3] **to 2023, approximately BRL 245 billion were allocated in the CDE** to finance public policies of the Brazilian electric sector, as shown in Figure 8.

Figure 8. Distribution of the total allocation of CDE resources from 2013-2023.



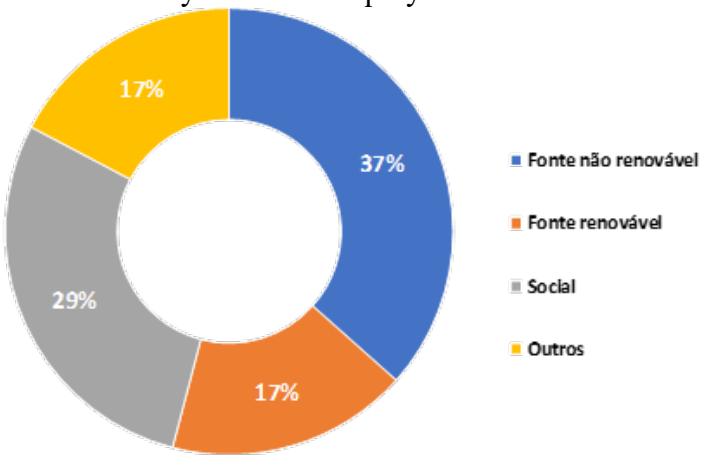
Of this amount, the main allocations up to 2023 were: **33% for the CCC**, **32% for tariff subsidies** or discounts **on distribution**[4]; **14% for the electricity tariff for low-income families**; **5% allocated for the universalization of access to electricity**; **4%** directed to **national coal-fired thermal power plants**; 3% to subsidies in transmission; and 9% for other public policies.

[3] First year of the data series available on Aneel website (Aneel, 2023).

[4] Compensation to distributors for revenue loss due to the concession of tariff discounts to users of services: (i) generator and consumer of an incentivized source; (ii) irrigation and aquaculture activity in a special schedule; (iii) distribution agent with its own market of less than 500 GWh/year; (iv) public water, sewerage, and sanitation service; (v) rural class; (vi) rural electrification cooperative subclass; and (vii) public irrigation service subclass (CCEE, 2023).

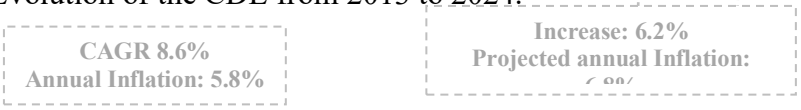
These six allocations accounted for over 90% of the total, while the remaining 9% were directed to nine other programs, five of which were discontinued[5], as shown in Figure 8.
Additionally, it is noted that 37% is allocated to finance polluting sources such as fuel oil, diesel through the CCC, and national coal, which has an exclusive allocation in the CDE. This allocation is more than double the resources earmarked for the development of renewable sources, as shown in Figures 8 and 9.

Figure 9. Renewability and social equity of CDE resource allocation.

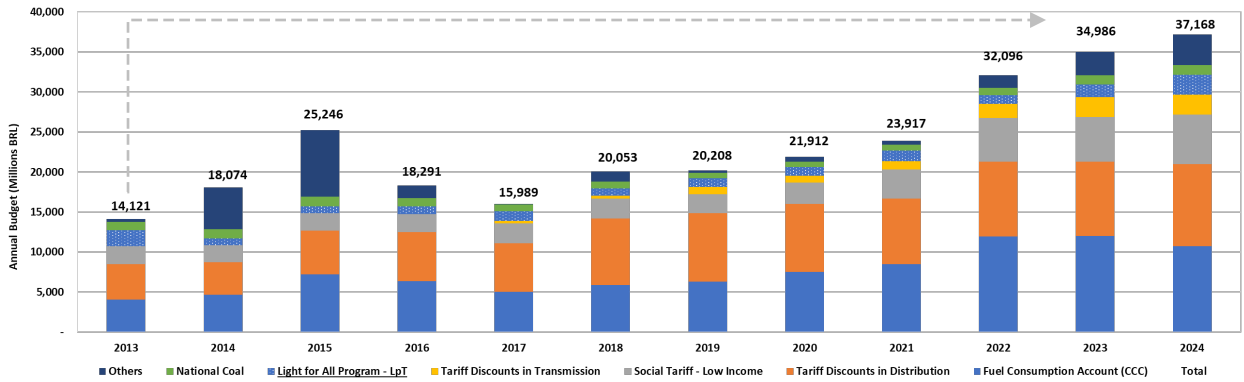


In 2013, the resources made available to the CDE amounted to BRL 14.1 billion; by 2023, the total reached BRL 35.0 billion, representing a Compound Annual Growth Rate (CAGR) of 8.6% per year. This rate was 2.8% higher than the average annual inflation calculated for the same period (5.8% per annum[6]).
In 2016 and 2017, there were reductions of 28% and 13%, respectively, in the total CDE resources. From this period on, these resources began to show an annual growth of 9.7%, significantly higher than the average annual inflation of 5.2% per annum calculated for the same period[7].
The evolution of this allocation, illustrated in Figure 10, makes it clear that, in all years, the largest allocation of resources was for the CCC. Among the six largest allocations, the rural subsidy was the only one that showed a decrease: a drop of almost 90% in the last five years.
Resources for national coal decreased by 41% between 2014 to 2020 but began to grow and stabilize after Law No. 14,299/2022, which included the energy source in the Just Energy Transition Program (TEJ), maintaining the mandatory purchase of energy generated from national coal-fired thermal power plants (Brazil, 2022), which have high greenhouse gas emissions according to a recent monitoring survey of plant operations (IEMA,2023).

Figure 10. Evolution of the CDE from 2013 to 2024.

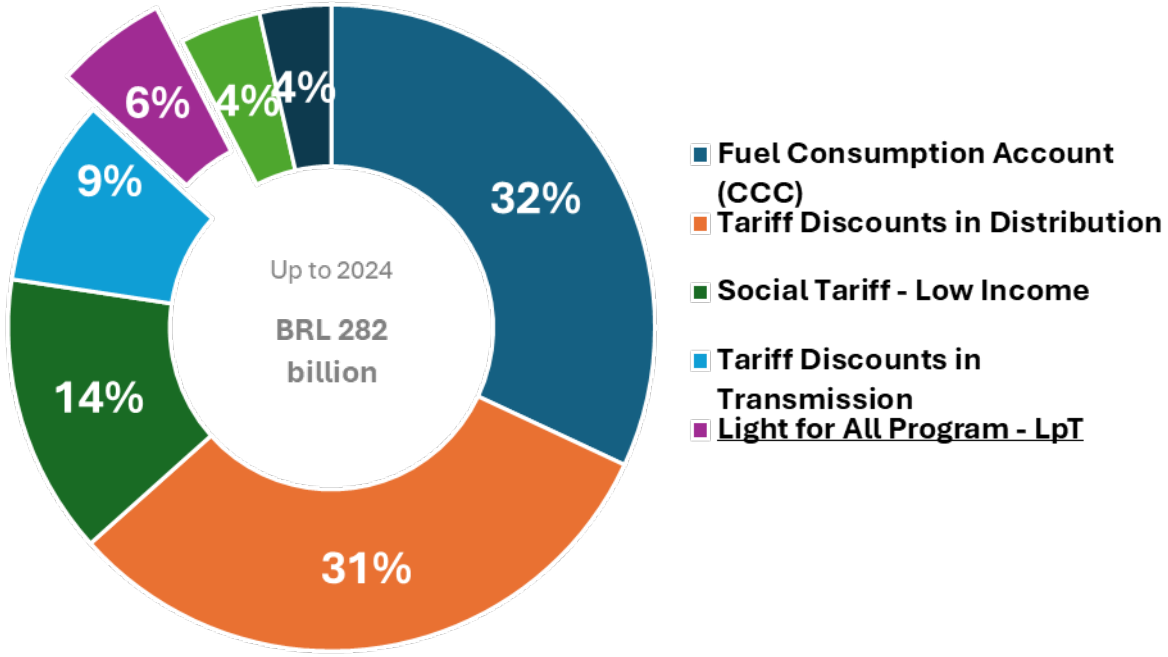


[5] Compensation of concessions, RTE subsidy, MME funds, QualMOT, and Technical Reserve (Aneel, 2023).
[6] The IPCA (IBGE) from 01/2013 to 09/2023 totaled 86.00%b(BCB, 2023).
[7] The IPCA (IBGE) from 01/2018 to 09/2023 totaled 36.29% (BCB, 2023).



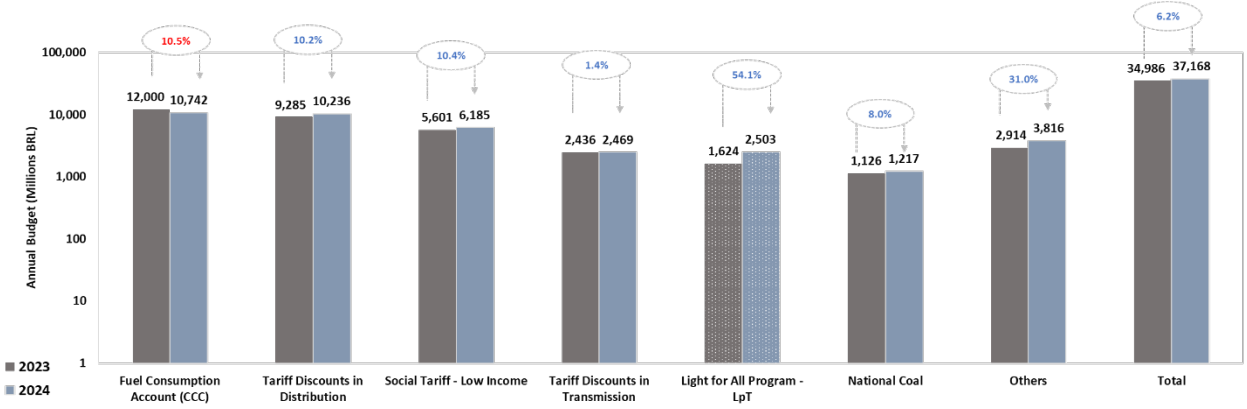
For 2024, the proposed budget is BRL 37.3 billion, an increase of 6.2% compared to 2023, below the estimated IPCA for 2024 of 6.8% (CCEE, 2023). **Resulting in more than BRL 282 billion allocated to the CDE over 12 years**, as shown in Figure 11.

Figure 11. Allocation of the totalization of CDE resources from 2013-2024.



Among the six main resource allocations, the CCC was the only one to see a reduction, -10.5%. Incentives for renewable sources and the social tariff experienced increases of 10.2%, 1.4%, and 10.4%, respectively, for tariff subsidies in distribution, transmission, and the social tariff. The subsidy for national coal increased by 8%, maintaining constant growth over recent years, as shown in Figure 12.

Figure 12. Allocation of CDE resources for 2023 and proposed for 2024.



8. Financial Resources for the LpT Program

The financial resources of the Light for All Program (LpT) come from the CDE, which contributes 90% of the funding. The remaining 10% comes from the counterpart contributions of the executing agents (MME, 2020). These CDE resources are transferred to the executing agents through the economic subsidy mechanism, intended to cover direct and indirect expenses under the supervision of ANEEL and the MME, as shown in Figure 13.

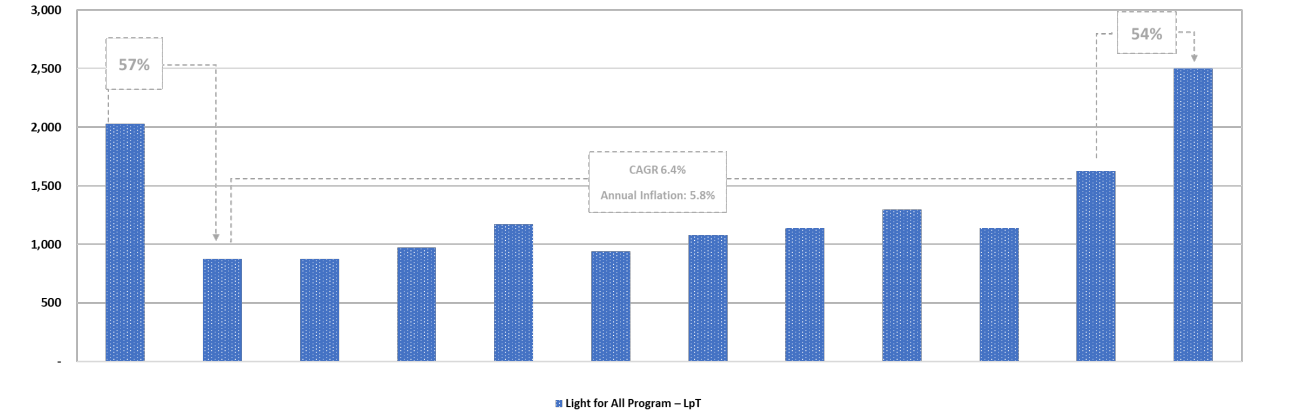
Since 2020, more than BRL 600 million has been disbursed to electric utility companies **for the installation of 14,191 systems** (MME, 2023), at an **average cost of BRL 45,320.26 per unit**. Based on this average cost, the necessary amount to serve all consumer units with the smallest system, SIGFI 45 kWh/month, would be around BRL 9.3 billion – close to the BRL 9.4 billion allocated by the new Growth Acceleration Program (PAC) for the universalization of access and use of electricity in remote regions of the Legal Amazon (Casa Civil, 2023).

Regarding the evolution of resource allocation for universalization of access**, in 2013, the resource allocated for the LpT program totaled BRL 2 billion**. The following year**, in 2014, there was a significant reduction of almost 57% to BRL 875 million**. Since then, the resources have had a Compound Annual Growth Rate (CAGR) of 6.4%, which is 0.6% higher than the average annual inflation for the same period (5.8% per annum[8]). This growth pattern continued until **2023**, when the amount allocated **reached a total of BRL 1.6 billion**.

Also in 2023, the MME revised the universalization targets and resource allocation for the year **2024**, earmarking **BRL 2.5 billion**, the highest amount provided so far and 53.7% higher compared to the previous year.

Figure 13. Annual resource allocation for the LpT Program.

[8] The IPCA (IBGE) from 01/2014 to 09/2023 totaled 75.62% (BCB, 2023).



9. Conclusions and Recommendations

To serve all electricity consumer units under the SIGFI 180 configuration would require spending more than BRL 25 billion, while employing SIGFI 45 would total, at a minimum, BRL 7.2 billion.
Universalization using **SIGFI 180 with lead-acid batteries** would necessitate the acquisition of **more than 15 million pieces of equipment** and the second-highest financial outlay, amounting **to BRL 25.2 billion. In contrast, the same system with lithium-ion batteries would encompass 9.9 million pieces of equipment with a higher expenditure of BRL 38 billion**.
The use of SIGFI 45 with lead-acid batteries would require more than 9.8 million pieces of equipment, three times the number of the SIGFI 45 with a lithium-ion battery, but would cost half as much, **at BRL 7.2 billion**. **Meanwhile, the system with lithium-ion batteries would demand 3.6 million pieces of equipment and BRL 14 billion** — the smallest number of equipment and the second-lowest financial disbursement compared to the other three cases (Table 4).

Table 4. Equipment and costs by system type.

System	Number of Equipment	Cost [BRL]
SIGFI 180 | Lead-Acid Battery	15,652,212	25,182,110,254
SIGFI 180 | Lithium-Ion Battery	9,826,554	38,033,695,294
SIGFI 45 | Lead-Acid Battery	9,489,166	7,205,579,156
SIGFI 45| Lithium-Ion Battery	3,663,508	14,021,143,890

Regardless of the scenario chosen, **the quantity of equipment required to universalize access to energy would alter the landscape of installed photovoltaic generation capacity in the Northern Region, as well as the national energy storage chain via batteries. The increased demand would put pressure on the solar photovoltaic and battery chains** for the supply and maintenance of millions of installed units in the region.
The financial resources to be allocated to the LpT program reinforce the social nature of the service. Although the program's objective is to foster socioeconomic development through access to electricity, the resource allocation per consumer unit indicates a trend of service delivery via SIGFI 45, which is capable of supplying a limited amount of energy, as previously seen. In this sense, **the universalization program closely resembles the *Bolsa Família*, providing energy for the basic needs of families.**

It is recommended that the increase in financial resources for the LpT program, as occurred in 2023, **be maintained in the coming years to ensure the achievement of goals**. Regarding the CDE, the MME and ANEEL could reallocate resources from the coal subsidy and part of the subsidy for financial incentives for alternative sources towards the universalization of energy access.

In the first case, it is incongruous to subsidize coal generation, which has significant economic, socio-environmental, and climatic impacts, at the expense of universalizing access to energy for a population that has been neglected essential public services. In the second case, the development of universalization itself has the character of incentivizing alternative sources represented by photovoltaic generation and energy storage through batteries, mainly lithium-ion.

Finally, despite renewed political will to accelerate the universalization of access to electricity in Brazil, it is crucial that these goals be reviewed, refined, and advanced annually, receiving the appropriate resources for the implementation and monitoring of systems.

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1. Off-grid refers to a system that is disconnected from the local utility's distribution network.
2. The quantification of the number of equipment necessary for the universalization of electric energy access in the Legal Amazon region is based on the number of systems implemented up to 2022 and the new goals of the Light for All Program (LpT) (IEMA, 2023).
3. The first year of the series available on the Aneel website (2023).
4. Compensation to distributors for revenue loss due to the concession of tariff discounts to users of services: (i) generator and consumer of an incentivized source; (ii) irrigation and aquaculture activity in a special schedule; (iii) distribution agent with its own market of less than 500 GWh/year; (iv) public water, sewerage, and sanitation service; (v) rural class; (vi) rural electrification cooperative subclass; and (vii) public irrigation service subclass (CCEE, 2023).
5. Compensation of concessions, RTE subsidy, MME funds, QualMOT, and Technical Reserve (Aneel, 2023).
6. The IPCA (IBGE) from 01/2013 to 09/2023 totaled 86.00% (BCB, 2023).
7. The IPCA (IBGE) from 01/2018 to 09/2023 totaled 36.29% (BCB, 2023).
8. The IPCA (IBGE) from 01/2014 to 09/2023 totaled 75.62% (BCB, 2023).