

# PDE 2035

Studies of the Ten-Year Energy Expansion Plan 2035

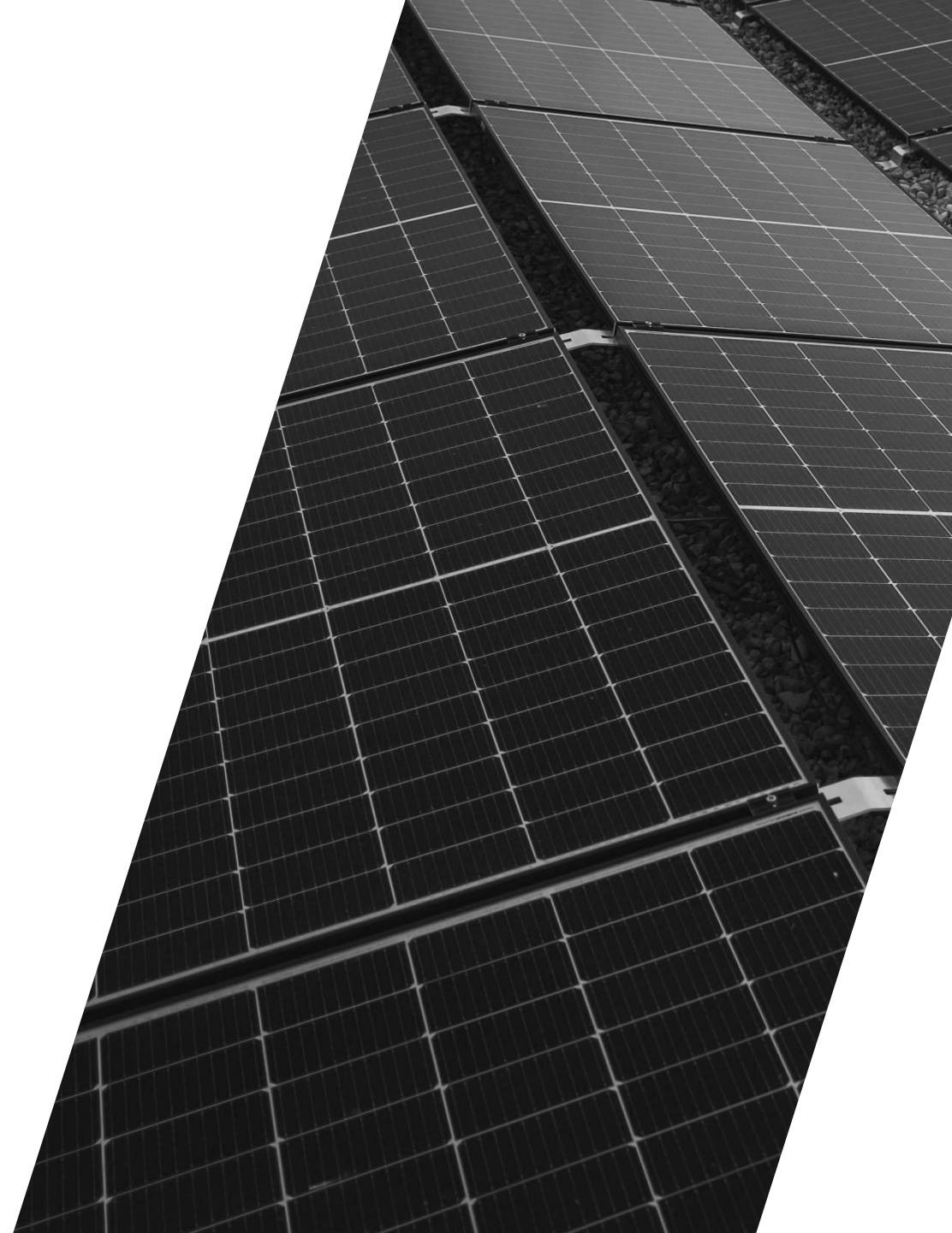
## Distributed Generation & Behind-the-Meter Battery Energy Storage

---

June 2025



MINISTÉRIO DE  
MINAS E ENERGIA



# TECHNICAL SHEET

**PDE 2035 | Studies of the Ten-Year Energy Expansion Plan 2035**  
Distributed Generation & Behind-the-Meter Battery Energy Storage



Minister of State for Mines and Energy  
**Alexandre Silveira de Oliveira**

Executive Secretary  
**Arthur Cerqueira Valerio**

National Secretary for Electric Power  
**Gentil Nogueira de Sá Junior**

National Secretary for Geology, Mining and Mineral Processing  
**Ana Paula Lima Vieira Bittencourt**

National Secretary for Oil, Natural Gas and Biofuels  
**Pietro Adamo Sampaio Mendes**

National Secretary for Energy Transition and Planning  
**Gustavo Cerqueira Ataíde**

[www.mme.gov.br](http://www.mme.gov.br)

*Staff Composition as of June 26, 2025*

Rio de Janeiro, 2025

Cover photo: Michael  
Pointner, Pexels.



President  
**Thiago Guilherme Ferreira Prado**

Director for Energy Economics and Environmental Studies  
**Thiago Ivanoski Teixeira**

Director for Power System Studies  
**Reinaldo da Cruz Garcia**

Director for Oil, Gas and Biofuels Studies  
**Heloisa Borges Bastos Esteves**

Director for Corporate Management  
**Carlos Eduardo Cabral Carvalho**

[www.epe.gov.br](http://www.epe.gov.br)

# TECHNICAL SHEET

**PDE 2035 | Studies of the Ten-Year Energy Expansion Plan 2035**  
Distributed Generation & Behind-the-Meter Battery Energy Storage

Energy Research Office - EPE

## Executive Coordination

Thiago Ivanoski Teixeira

## Technical Coordination

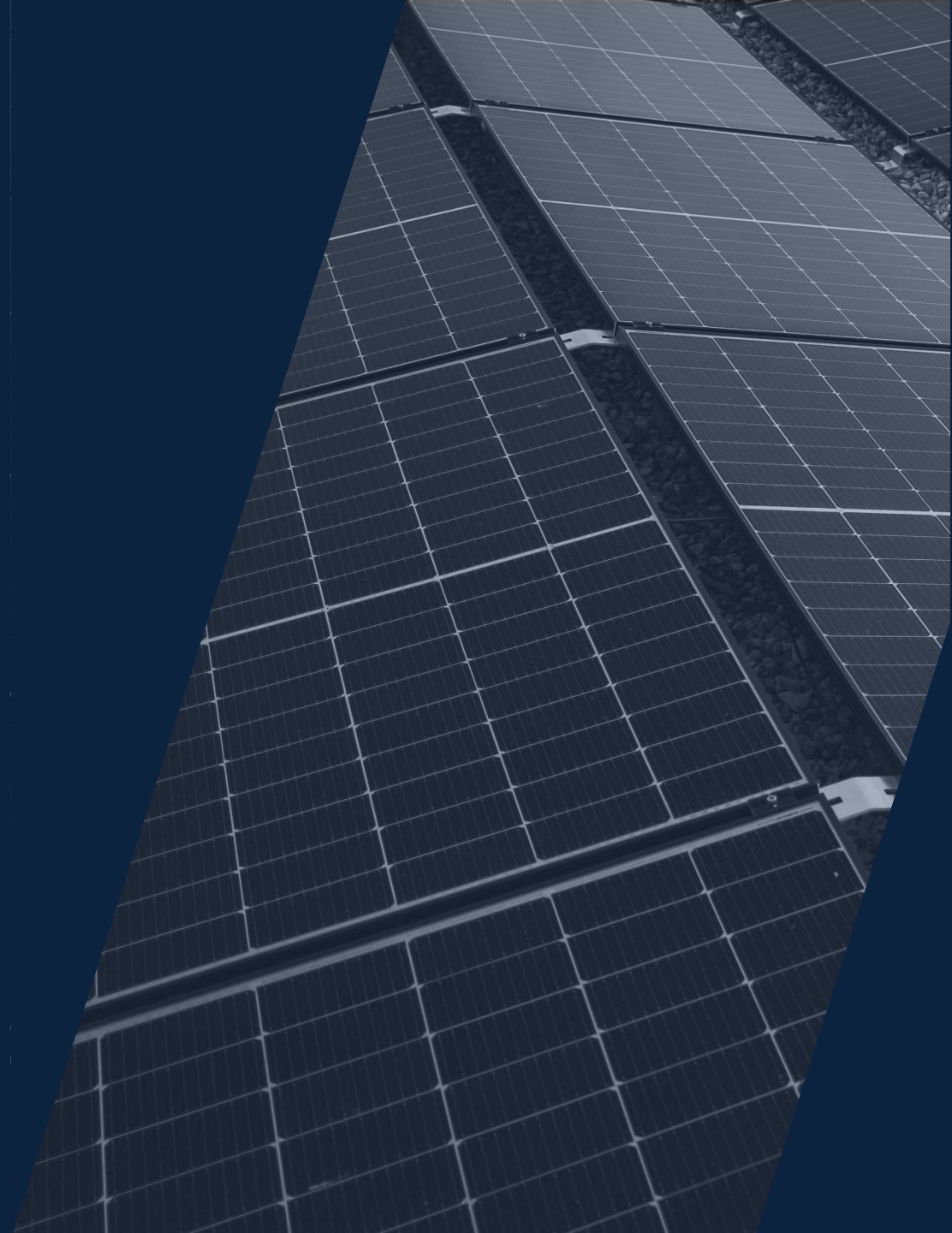
Arnaldo dos Santos Junior  
Carla da Costa Lopes Achão

Gabriel Konzen  
Gustavo Naciff de Andrade

## Authors

### Department of Energy Economic Studies

Allex Yujhi Gomes Yukizaki  
Arthur Mendonça Quinhones Siqueira  
Caroline Chantre Ramos  
Kevyn Matheus Vieira Nogueira  
Simone Saviolo Rocha  
Thais Accioly Araujo



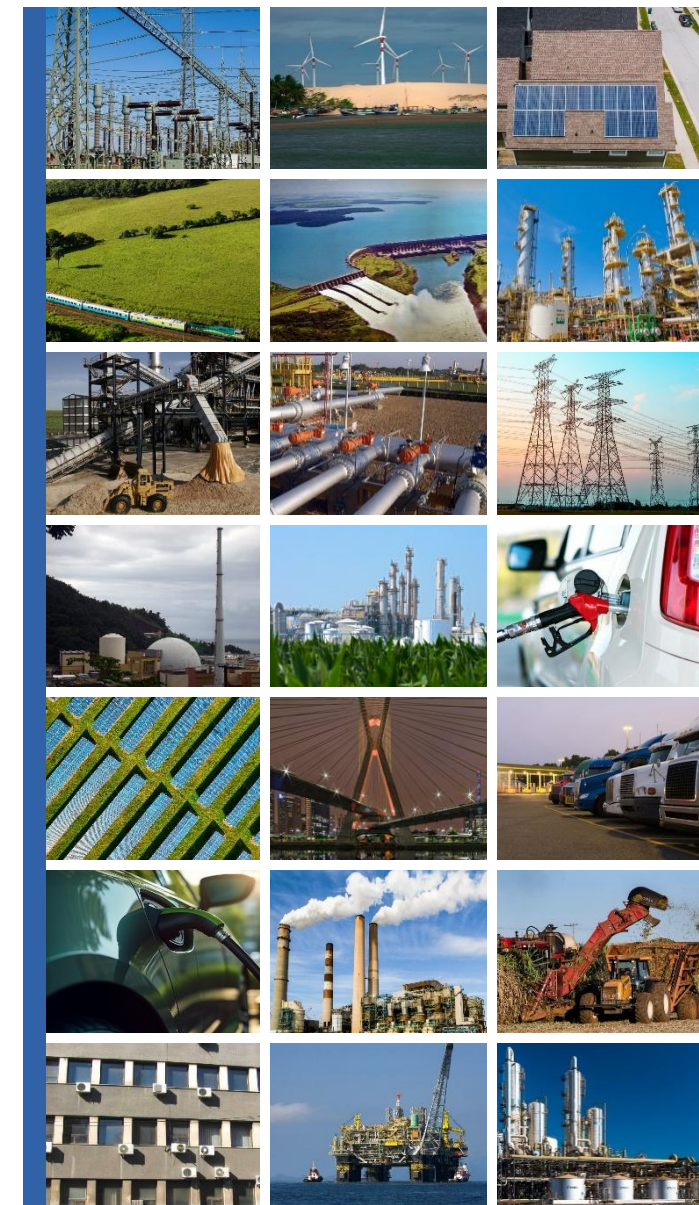
# PDE 2035

## Distributed Generation & Behind-the-Meter Battery Energy Storage

### Public Value

The studies of the Ten-Year Energy Expansion Plan (PDE) guide the formulation of public policies, help direct the decisions of various stakeholders — such as governments, companies, and civil society — and contribute to the country’s energy security.

Distributed Energy Resources represent a paradigm shift in the Brazilian Electric Sector. Integrating them into energy planning is essential to guide public policies, new investments, and the operation of the Brazilian Electric Sector. For example, projections of distributed generation guide the expansion of centralized generation and influence pricing models in the sector. In general terms, the analyses presented in this report help reduce information asymmetry among agents, providing inputs for better decision-making by both public and private entities.



# NOTICES

For simplicity, this report uses the term distributed generation (DG). However, unless otherwise stated, it specifically refers to the regulatory framework of micro and mini distributed generation (MMDG) in Brazil, as initially defined by ANEEL Resolution No. 482/2012 and subsequently by Law No. 14,300/2022. In contexts where scale is particularly relevant—such as in battery simulations for residential self-consumption—the term small-scale distributed generation may be applied to refer specifically to microgeneration systems.

This publication contains projections regarding future events that reflect the perspective of the Energy Research Office within the scope of the Ten-Year Energy Expansion Plan 2035 (PDE 2035). Such projections involve a wide range of known and unknown risks and uncertainties and, therefore, the data, analyses, and any information contained in this document are not guarantees of future outcomes or achievements.

This document is of an informative nature and is intended to support the planning of the national energy sector.

Energy Research Office disclaims responsibility for any actions and decisions that may be taken by any individual or legal entity based on the information contained in this document.

**PDE** 2035

# Distributed Generation



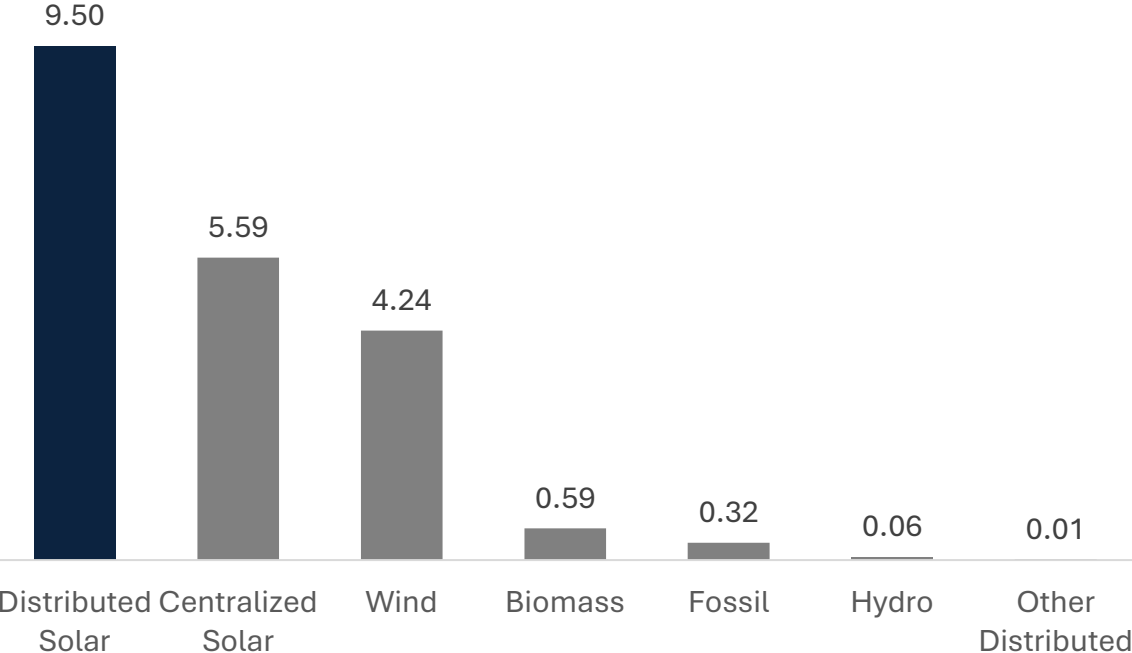
MINISTÉRIO DE  
MINAS E ENERGIA



# Distributed Generation (DG) has stood out in recent years

MMDG has been a key driver of the expansion of installed capacity in Brazil. In 2024, **for the fourth consecutive year, distributed solar power surpassed the expansion of other sources** in terms of installed capacity.

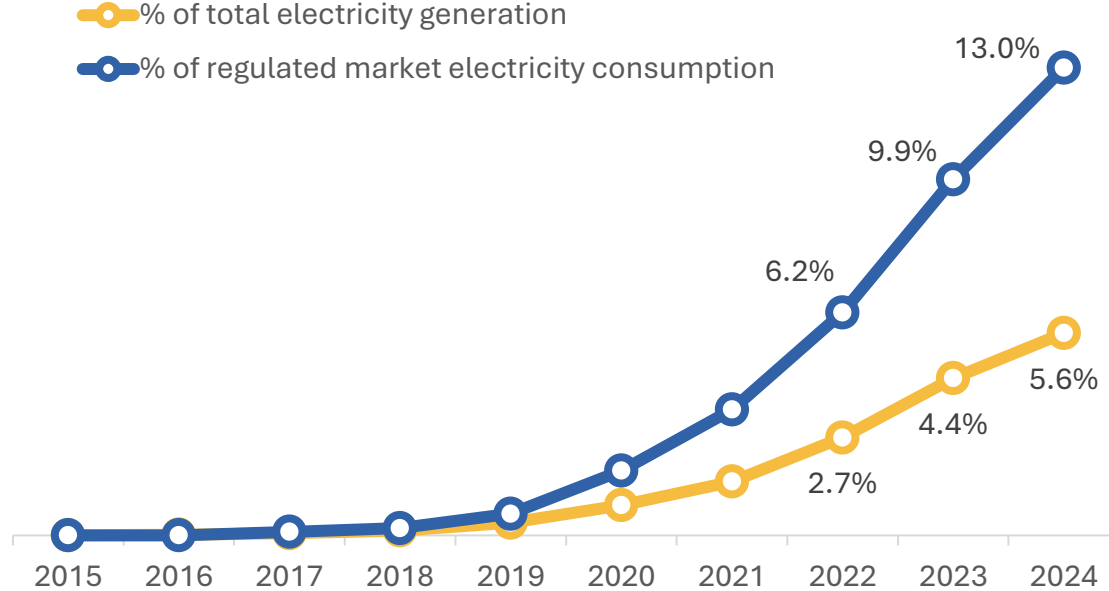
Electricity Generation Capacity Additions in 2024 [GW]



Source of data: ANEEL. RALIE Interactive Panel (March 2025) and MMDG database (accessed on 03/14/2025)

MMDG has also gained importance regarding its contribution to electricity supply, **accounting for 5.6% of total generation in Brazil and approximately 13% of regulated market consumption nationwide.**

Participation of MMDG in the national market



Source of data: EPE. 2025 Summary Report and Brazilian Distributed Generation Dashboard.



Access the [2025 Summary Report of the National Energy Balance](#) for more information.

# Brazil's Legal Framework for Distributed Generation

## Law No. 14,300/2022

- In January 2022, Law No. 14,300 was published, establishing the Legal Framework for Distributed Generation.

### Main changes introduced by the Law:

- The threshold for mini distributed solar PV was reduced from 5 MW to 3 MW;
- Dispatchable sources were defined as hydro, biomass, cogeneration and PV combined with batteries;
- Authorization for battery storage and hybrid systems, subject to future regulation;
- Reduction in availability charges;
- Authorization for fractioned floating plants, which, when aggregated, may exceed the 3 MW limit;
- Establishment of the Social Renewable Energy Program, aimed at contracting distributed generation (DG) to supply low-income consumers.

<sup>1</sup> TUSD Distribution refers to the distribution component of the Distribution System Usage Tariff (TUSD)

<sup>2</sup> TUSD Transmission refers to the transmission component of the Distribution System Usage Tariff (TUSD)

<sup>3</sup> R&D refers to the regulatory charge for research and development projects in the electricity sector; PEE to the charge that finances energy efficiency programs; and TFSEE to the inspection fee that covers ANEEL's regulatory and supervisory activities.

<sup>4</sup> TE Energy refers to the Energy component of the Energy Tariff (TE).

## How will the compensation rules for injected energy into the grid work?

- For existing generators and those who submitted an access request within 12 months after the Law's publication, compensation covering all tariff components (the original rule) is granted until 2045;
- For new generators (requests submitted after 01/08/2023):

Charge on credits	2023 to 2028	2029+
TUSD Distribution <sup>1</sup>	Gradual charge from 15% to 90%	Rule to be defined

- Exception: for new generators above 500 kW from non-dispatchable sources, with remote generation or shared systems where a single holder has more than 25% of injection participation:

Charge on credits	2023 to 2028	2029+
TUSD Distribution <sup>1</sup>	100%	Rule to be defined
TUSD Transmission <sup>2</sup>	40%	
R&D, PEE and TFSEE charges <sup>3</sup>	100%	

From 2029 onwards, compensation will be based on TE Energy<sup>4</sup> + benefits. ANEEL will establish the methodology for valuing the benefits of MMDG, following the guidelines set by CNPE through Resolution No. 2, of April 22, 2024.

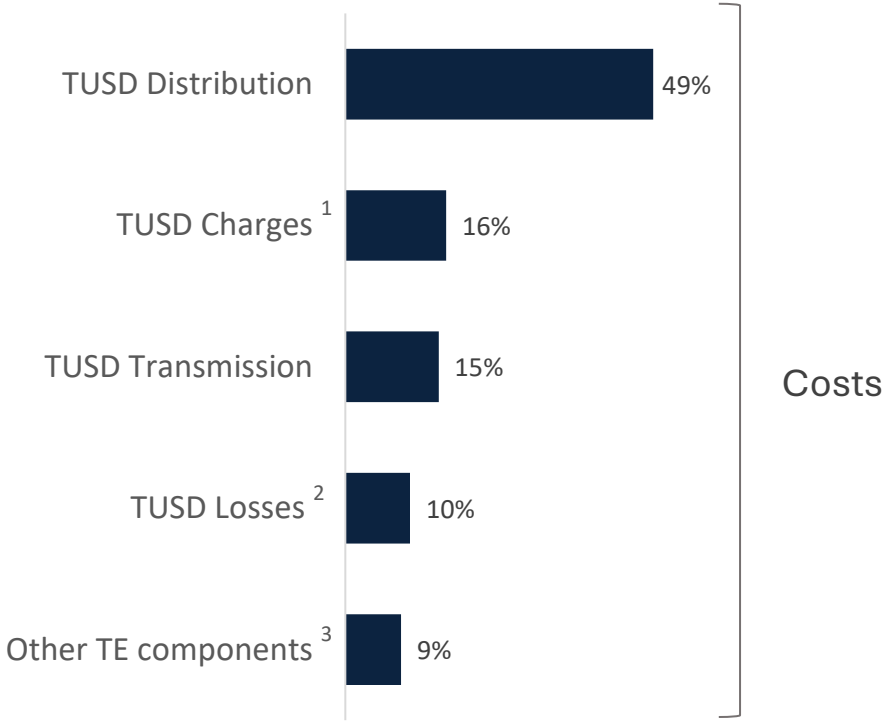
# Scenarios for Distributed Generation

### Uncertainties in the valuation of benefits

- Law No. 14,300 sheds light on the likely regulatory scenario for MMDG. However, despite the guidelines for valuing MMDG’s costs and benefits having been established through CNPE Resolution No. 2/2024, **there are still uncertainties related to tariffs for energy injected into the grid from 2029 onwards**, stemming from the methodology for calculating MMDG benefits for the electricity sector;
- This uncertainty arises from the fact **that ANEEL must define this methodology in accordance with the guidelines set forth in the Resolution and with the necessary public consultation**. The study is scheduled in the Regulatory Agenda of the Agency for the second half of 2026;
- Even though remuneration will only be affected as of 2029, **the definition of the methodology is expected to influence investments throughout the decade**, as it impacts the cash flow of these projects.

The definition of the valuation methodology for MMDG also reflects a broader debate on how the costs of the electricity infrastructure will be shared among different consumer profiles.

### Average percentage of each component in tariff 2024 B1, excluding the Energy portion of TE



Source of data: ANEEL  
<https://portalrelatorios.aneel.gov.br/luznatarifa/basestarifas>

<sup>1</sup> TUSD Charges refers to the sectoral charges embedded in the Distribution System Usage Tariff (TUSD).  
<sup>2</sup> TUSD Losses refers to the charge covering technical and non-technical losses in the system in the Distribution System Usage Tariff (TUSD).  
<sup>3</sup> Other TE components to additional elements of the Energy Tariff not directly related to the energy purchase itself.

# Scenario Results

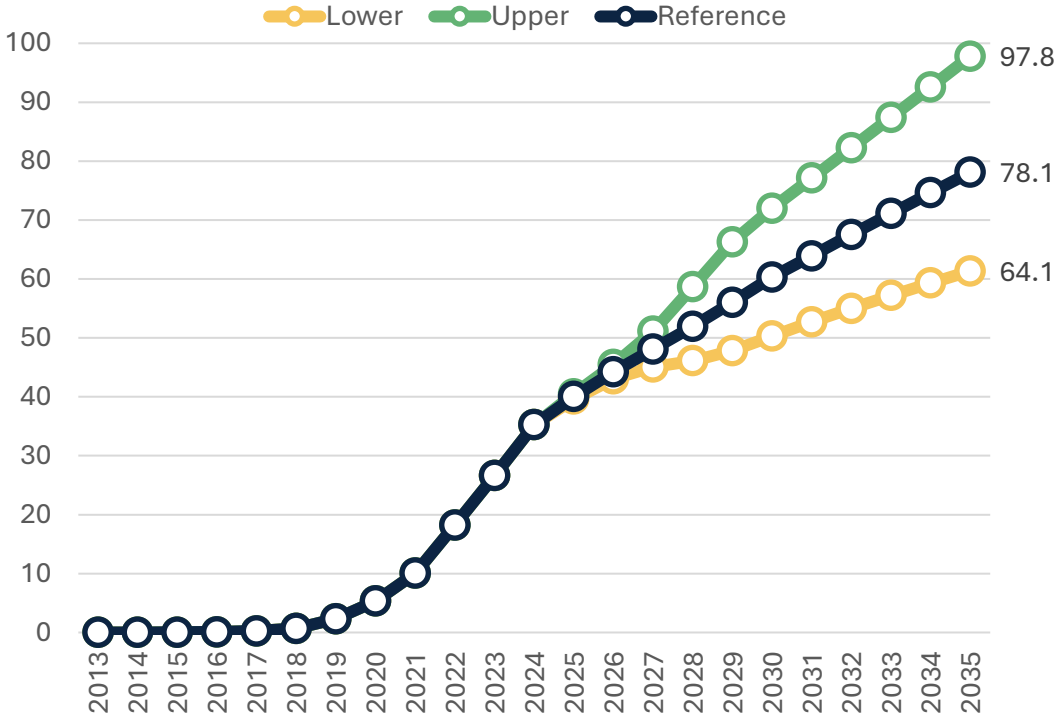
- 1 Upper Scenario**  
 Simulates **compensation from 2029 onwards equal to TE Energy + 100% of costs**, which would mean restoring the original 1-to-1 compensation.
- 2 Reference Scenario**  
 Considers **only the charge of 100% of TUSD Distribution as of 2029**. This implies that about 50% of the costs will be offset through benefits.
- 3 Lower Scenario**  
 Simulates compensation from 2029 onwards limited to the **TE Energy** component only.

## Summary of Results

By Scenario

Scenario	Adopters (2013-2035) million	Capacity (2013-2035) GW	Generation (2035) GW average	Investments (2025-2035) BRL billion
Upper	12.1	97.8	15.2	155.9
Reference	9.5	78.1	12.1	105.7
Lower	7.5	61.4	9.4	62.8

Projection of Installed Capacity of MMDG (GW) By Scenario



Note: Projection baseline date: November 2024.

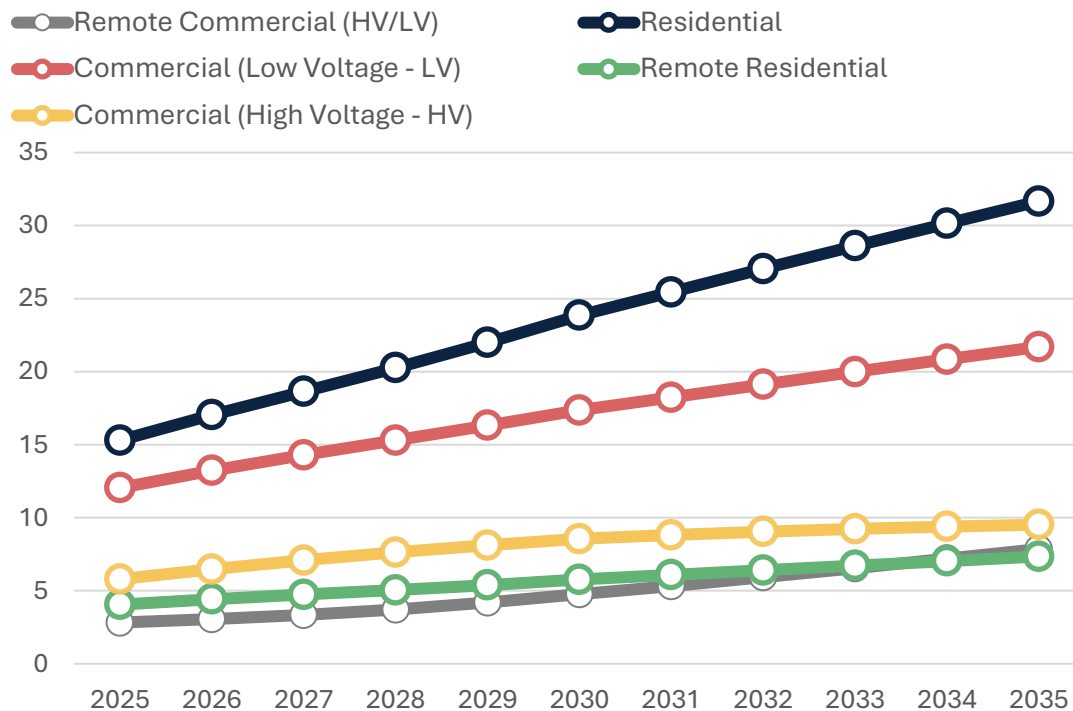


Access the [model](#) used in the projections and its [methodology](#).

# Details of the Reference Scenario

## Projection of installed MMDG capacity (GW)

By segment

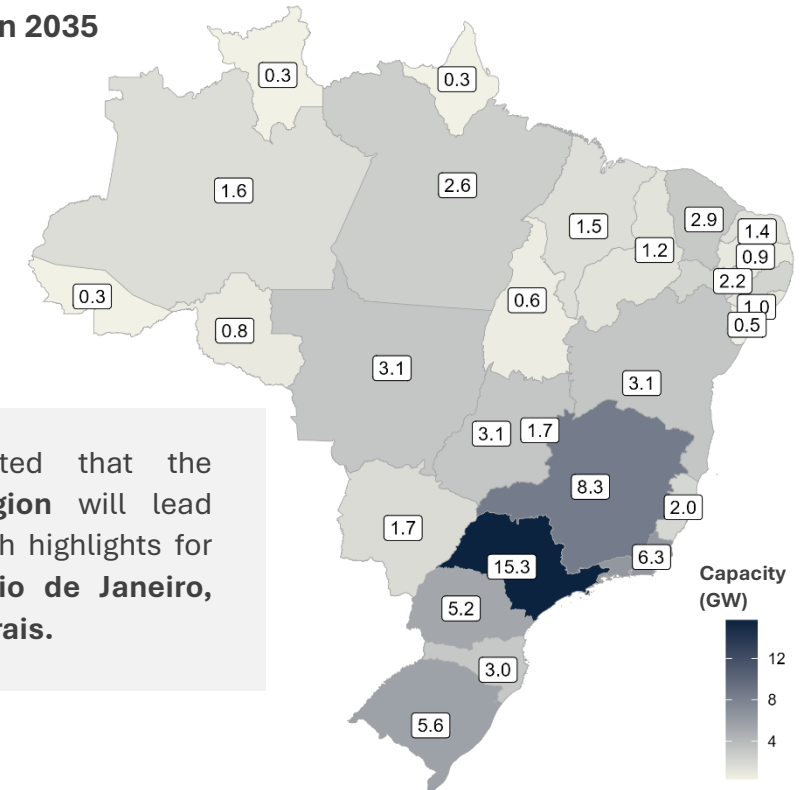


Note: Remote Commercial (HV/LV) refers to mini generation systems connected at High Voltage units, but that offset credits remotely in Low Voltage.

**The residential segment** is expected to be the leader in installed capacity in the Reference Scenario.

## Projection of installed MMDG capacity in 2035 (GW)

By state

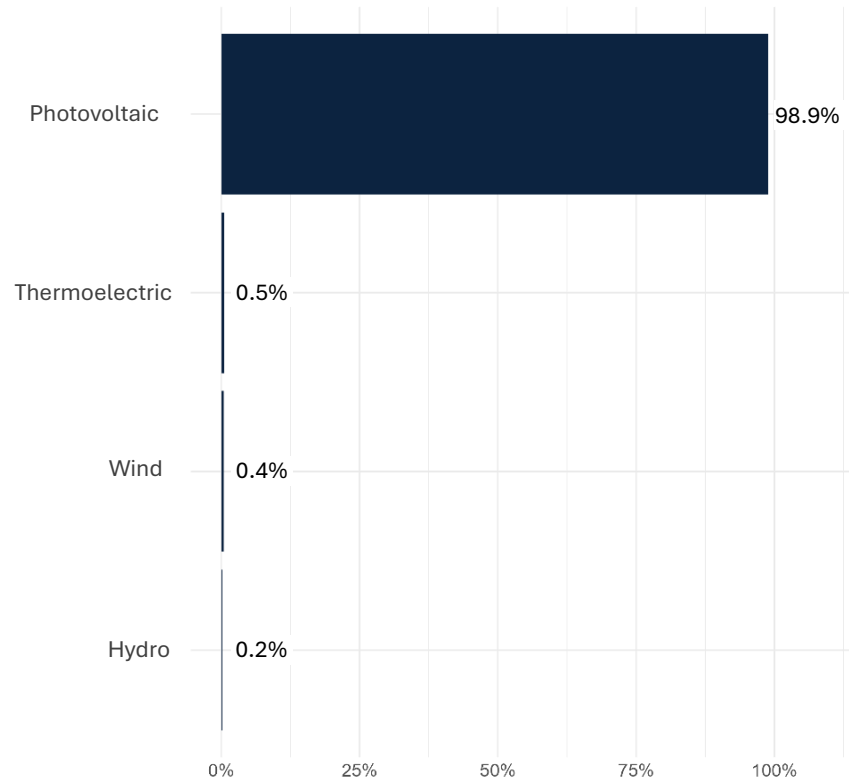


## Projection of additional capacity from 2025 to 2035 by region

	Southeast	Northeast	South	North	Midwest
Capacity Added (GW)	+20.3	+9.2	+5.8	+3.8	+3.8
Growth 2025 - 2035	172%	133%	73%	143%	63%

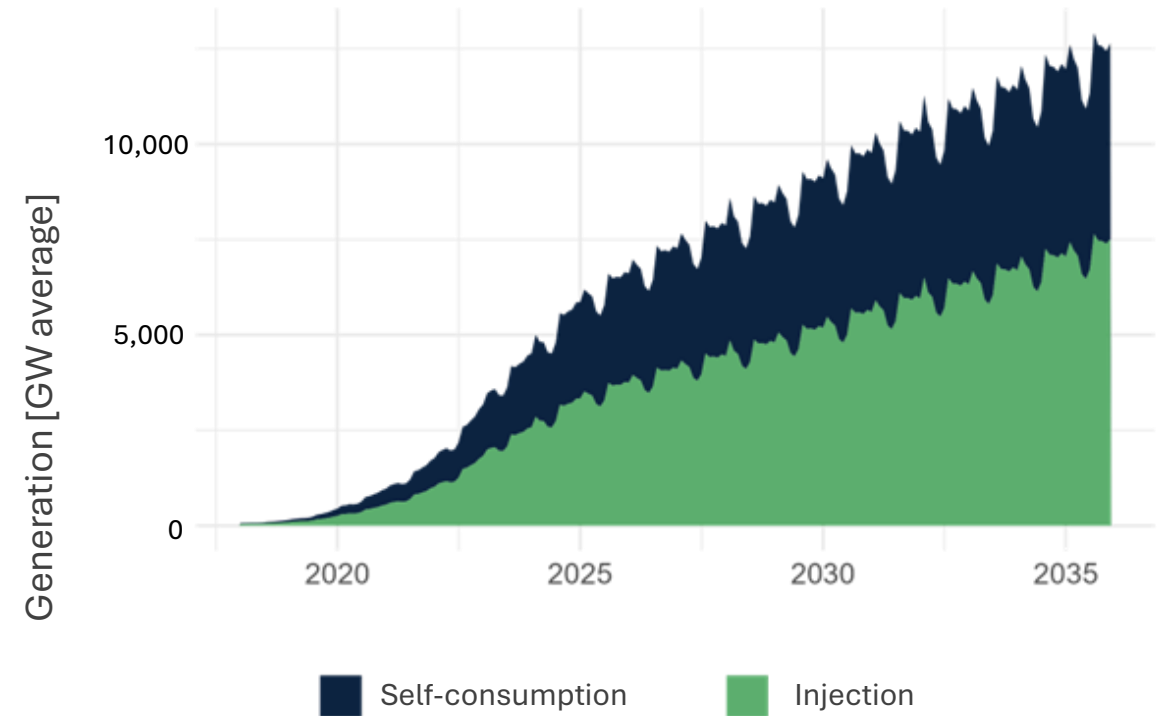
# Details of the Reference Scenario

Share by source in 2035  
Reference Scenario



**Solar Photovoltaic remains the predominant source among generation technologies.**

Projection of monthly generation in average MW, by component<sup>1</sup>  
Reference Scenario



(1) Breakdown by component is an estimate based on typical factors by source and market segment.

# Behind-the-Meter Battery Energy Storage

# Behind-the-Meter Battery Energy Storage Systems (BTM BESS) have the potential to provide multiple services to the power sector

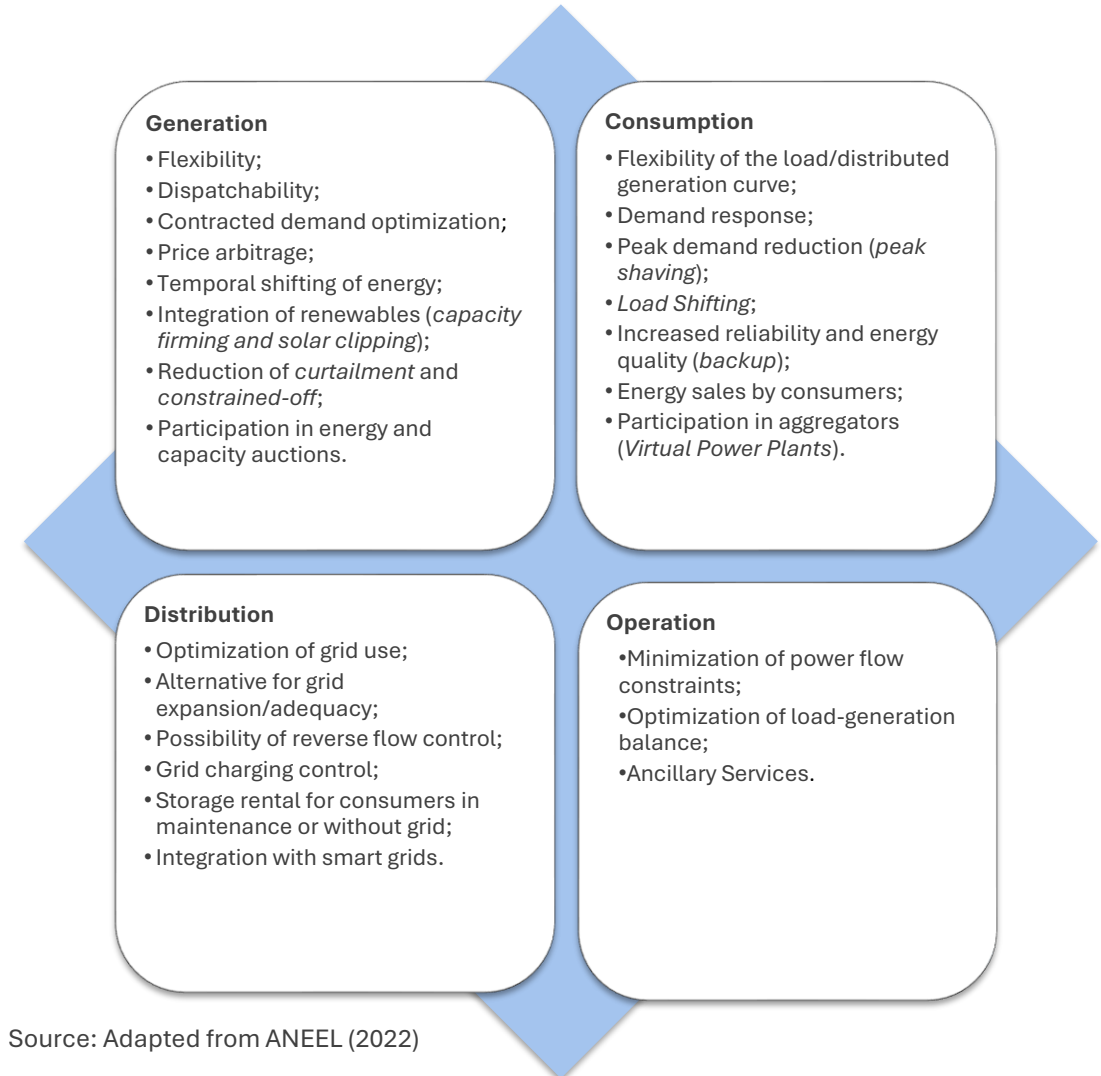
- **Behind-the-Meter Battery Energy Storage System (BTM BESS) is a multifunctional** solution with recognized technical potential to operate across different segments of the power system;
- At smaller scales, it allows more dynamic responses to local and seasonal constraints, enabling both temporary and structural solutions, with potential benefits in terms of cost and time. Thus, **BTM BESS emerges as a strategic resource for the modernization of power systems**

## The case of battery energy storage for controlling reverse power flow.

Cases of reverse power flow into the grid have been increasing in the National Interconnected System due to the spread of non-dispatchable plants operated by National Electricity System Operator, such as distributed generation.

Reverse power flow may increase the need for restrictions on centralized generation plants to ensure National Interconnected System's security criteria. Additionally, reverse flow may affect the performance of protection and power control equipment.

Systemic use of BESS for managing consumption and generation can contribute to retaining energy within the distribution network, preventing reverse flows at substations interfacing with the transmission system, and mitigating the evening ramp.

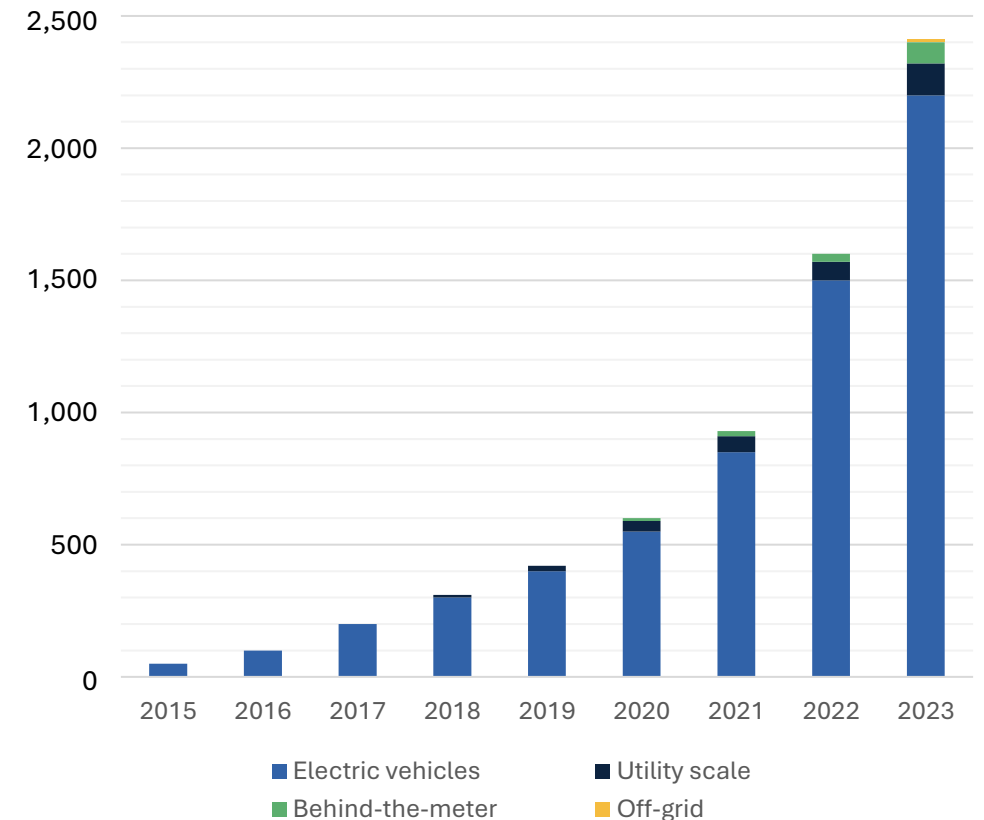


Source: Adapted from ANEEL (2022)

# Behind-the-Meter Applications Have Grown Internationally

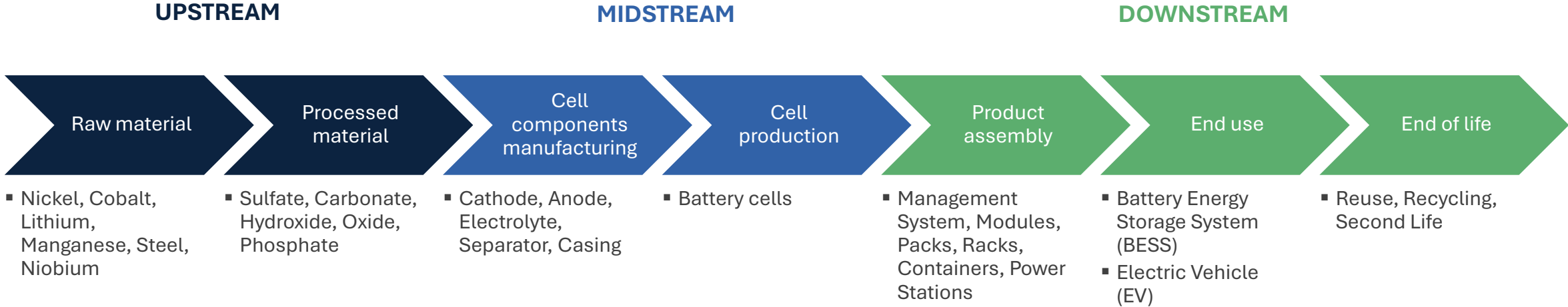
- The **global cumulative battery storage capacity** jumped from 1 GW (2013) to **85 GW (2023)**, with 42 GW added in 2023 alone.
- Batteries for Electric Vehicles (EVs) account for more than 90% of the accumulated market growth between 2015 and 2023;
- **The global stationary battery market (excluding EVs) doubled in 2023**, raising the total capacity in use to over 190 GWh;
- Behind-The-Meter Battery Energy Storage Systems accounted for about **30% of the stationary market in 2023** and showed a **2.5x increase** compared to 2022;
- The Utility-Scale segment has the largest share among solutions, **driven by policies for integration with renewable energy and grid stability**;
- The Off-Grid segment has significantly smaller participation, **but with growth potential in remote areas or with limited access to the grid**.

Evolution of lithium-ion battery capacity in use by application type (GWh)



Source: IEA (2024)

# Supply chain structure and international prices

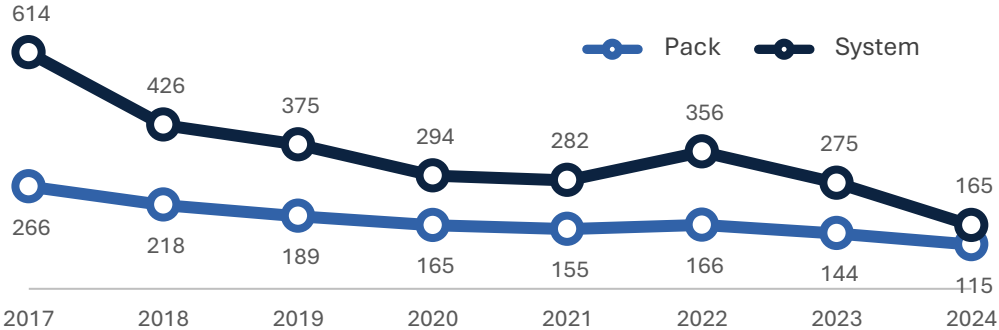


### Key aspects of the battery supply chain

- China leads with 85% of global cell production and holds a strong position in active materials as well as in the refining of critical minerals;
- Governments have a crucial role in shaping local and global supply chains to secure safe, sustainable, and affordable battery production;
- Lithium-ion technology was the dominant technology in the electric vehicle and energy storage market in 2023;
- BESS prices are projected to fall by 45% to 57% by 2035, along with improvements in energy density and lifetime.

Sources: IEA (2024); Bloomberg (2025)












Global lithium-ion battery prices (real terms, USD/kWh, 2024)



Note: The system price accounts for all project equipment, excluding EPC and grid interconnection.

Source: BloombergNEF (2024; 2025)

# Policies for Behind-the-Meter Battery Energy Storage in selected countries

	Financial support	Dynamic tariffs	Electricity market access
 Germany	●	●	●
 Australia	●	●	●
 Canada	●	●	●
 China	●	●	●
 South Korea	●	●	●
 USA	●	●	●
 India	●	●	●
 Italy	●	●	●
 Japan	●	●	●
 United Kingdom	●	●	●
 Brazil	●	●	●

Support Level ● Low ● Medium ● High

- **Incentive policies have played a crucial role in the development of the Behind-The-Meter Battery Energy Storage System (BTM BESS) market**, enhancing investment feasibility and enabling participation in electricity markets;
- In some countries, direct financial support is offered for the purchase of equipment. The Australian program Cheaper Home Batteries, for example, seeks to reduce the cost of a Battery Energy Storage System (BESS) by around 30%. The program has a budget of BRL 8.3 billion.<sup>1</sup> Brazil, as presented in the following section, has certain policies for the industrial supply chain and for battery financing;
- **The application of dynamic tariffs is another way to encourage BESS use**, i.e., differentiated tariffs according to the time of consumption. In Brazil, time-of-use tariffs provide some incentive. However, consumers served at low voltage face flat tariffs without hourly variation, which makes battery investment unfeasible;
- In several countries, **the participation of BESS in competitive electricity markets has been enabled**. This occurs through aggregators — agents that group multiple consumers and consolidate their storage capacity. Such participation allows consumers with BTM BESS to generate additional revenues.

Source: Adapted from IEA (2024)

<sup>1</sup> Conversion A\$1 AUD = BRL 3.615 (commercial exchange rate at 11:30 on 06/26/2025)

# Regulatory framework and battery incentive policies in Brazil

## Regulation

- ANEEL Normative Resolution No. 1,000/2021 and Module 3 of PRODIST (Distribution Rules and Procedures) authorize the connection of storage systems in consumer units. Regulatory improvements are foreseen in the Regulatory Roadmap formulated by the Agency (ANEEL, 2022);
- ANEEL has recognized the use of storage as an alternative for connecting MMDG projects in cases of reverse power flow.

## Financing

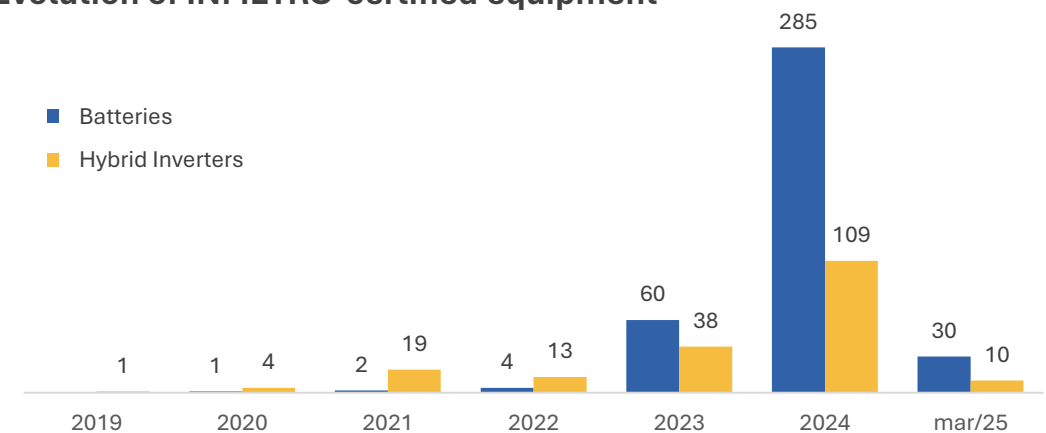
- The Brazilian Development Bank (BNDES), through its Machinery and Equipment Financing Program (FINAME), **offers credit lines with differentiated rates** for the acquisition of stationary energy storage systems, batteries, and electrolyzers.

## Industrial Policy

- The “*Nova Indústria Brasil*” (*New Industry Brazil*) program, in its 2024–2026 Action Plan, aims to progressively develop domestic battery manufacturing capacity to increase the competitiveness of the production chain through stationary applications and electric mobility.

- The Ministry of Development, Industry, Trade and Services (MDIC), through resolutions of the Executive Management Committee (Gecex) — the executive body of the Foreign Trade Chamber — grants reductions in the Import Tax when there is no equivalent domestic production of equipment classified under the Mercosur Common Nomenclature (NCM) 85 family, such as accumulators (85.07), batteries (85.06), and inverters (85.04).
- INMETRO Ordinance No. 140/2022 establishes mandatory technical requirements for equipment used in the generation, conditioning, and storage of electricity in photovoltaic systems, with the aim of ensuring the safety, performance, and quality of products marketed in Brazil.

## Evolution of INMETRO-certified equipment



Source: Author’s elaboration based on INMETRO, 2025

# Evolution of prices in Brazil

There are still **significant uncertainties** regarding the final price of BESS in Brazil, as costs may vary according to the supplier, as well as the **scale** and **configuration** of the project. In addition, changes in the **tax burden** applicable to these systems may also have a relevant impact on the final price.

## Commercial and industrial (C&I) systems

- According to data from ABSAE (2024), a BESS for commercial and industrial (C&I) applications (3 MWh) has a final price of around **BRL 2,000/kWh**, considering the current tax burden (see table below).

### Final price composition of a 3 MWh BESS with 3-hour autonomy

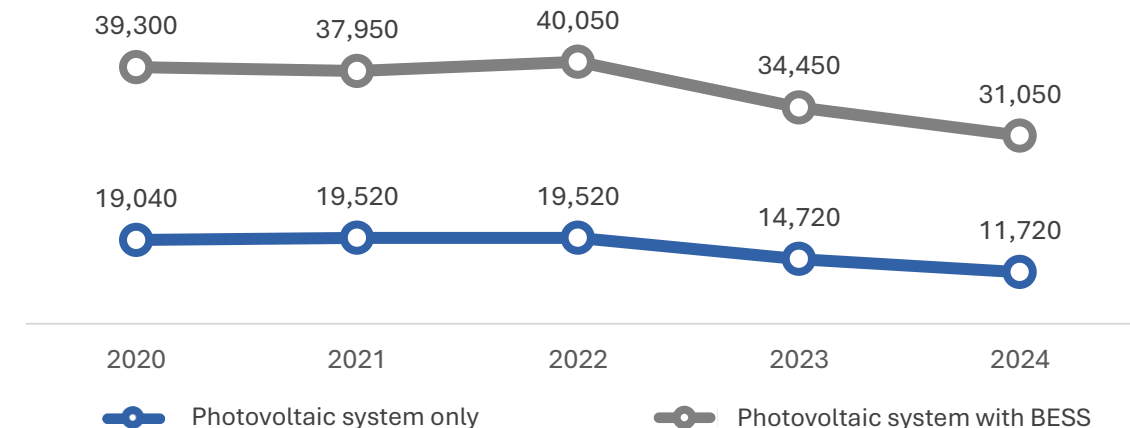
Components	C&I – 3 MWh
BESS CAPEX + equipment (FOB USD/kWh)	170.00
Logistics costs (% of CAPEX)	5.0%
EPC + BOS (% of CAPEX)	13.0%
National tax burden (%)	70.8%
<b>Installed BESS price (BRL/kWh)</b>	<b>1,920</b>

Source: ABSAE (2024)

## Residential systems

- Considering data from Greener (2025) for residential hybrid systems (photovoltaic generation and BESS), it is estimated that the final price of the BESS for residential consumers is close to **BRL 3,500/kWh**.

### Evolution of the final price of residential PV distributed generation systems with and without BESS (values in BRL)



Note: Considers a 4 kWp PV distributed generation system and a 5 kWh BESS.

Source: Author's elaboration based on data from Greener (2025a, 2025b)

# Simulated behind-the-meter battery energy storage (BTM BESS) applications

To assess the economic and operational potential of behind-the-meter energy storage, two complementary simulation approaches were developed, each focusing on a specific consumer profile and a distinct key application:

## 1. Consumption management under A4-Green tariff for consumers served at medium voltage in the regulated market

- **Objective:** to evaluate the circumstances in which battery energy storage system may replace diesel generators in reducing consumption during peak periods.

## 2. Increase of photovoltaic self-consumption in low-voltage consumers with small-scale (micro) distributed generation systems

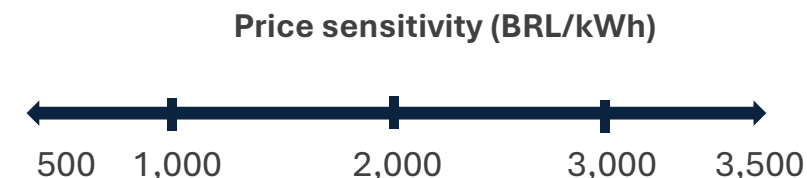
- **Objective:** to assess the economic feasibility of maximizing local consumption of the energy generated in low-voltage units that integrate photovoltaic systems with BESS.

### Key applications of BTM BESS in Brazil

	Conventional LV Tariff	Time-of-use LV Tariff	A4 Tariff (Green or Blue)
Backup and quality	✓	✓	✓
Peak demand reduction	✗	✗	✓
Load shifting	✗	✓	✓ Assessed
Increase in self-consumption of MMDG	✓ Assessed	✓	✓

### Sensitivity to storage system price

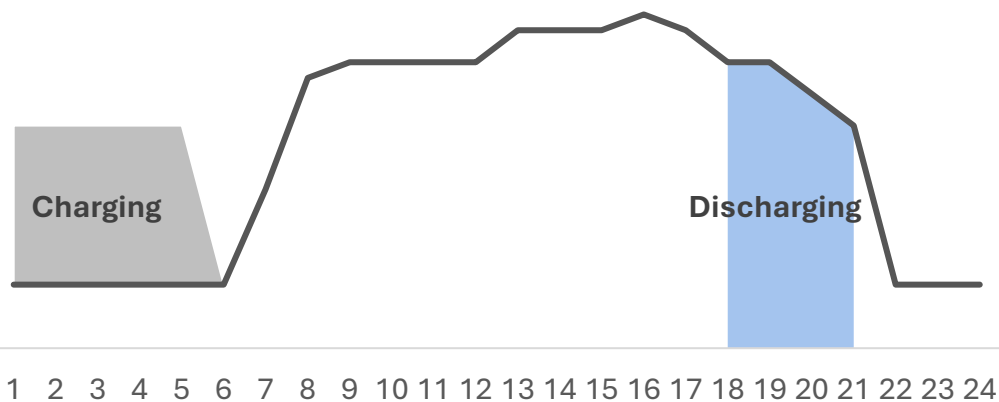
Given the uncertainties associated with the future cost of batteries, EPE carried out simulations considering a price range between BRL 500 and BRL 3,500/kWh. Through this analysis, it is possible to assess the economic feasibility of the solutions under different levels of investment.



# Application I: Consumption management under A4 – Green Tariff

- Since 1988, consumers served at high voltage have been subject to time-of-use tariffs, characterized by differentiated prices between peak and off-peak hours;
- BTM BESS can be strategically used to shift consumption from high-tariff periods (peak hours) to lower-cost periods (off-peak). The greater this tariff differential, the higher the attractiveness of batteries;
- It is worth noting that many consumers use diesel generators to avoid consumption during peak hours. In 2015, EPE estimated between 7–9 GW of generators for this purpose (EPE, 2015).

## Illustration of BTM BESS operation for Application I



## Tariff A4 Green Differential

### Peak (P) Tariff minus Off-Peak (OP) Tariff with Taxes

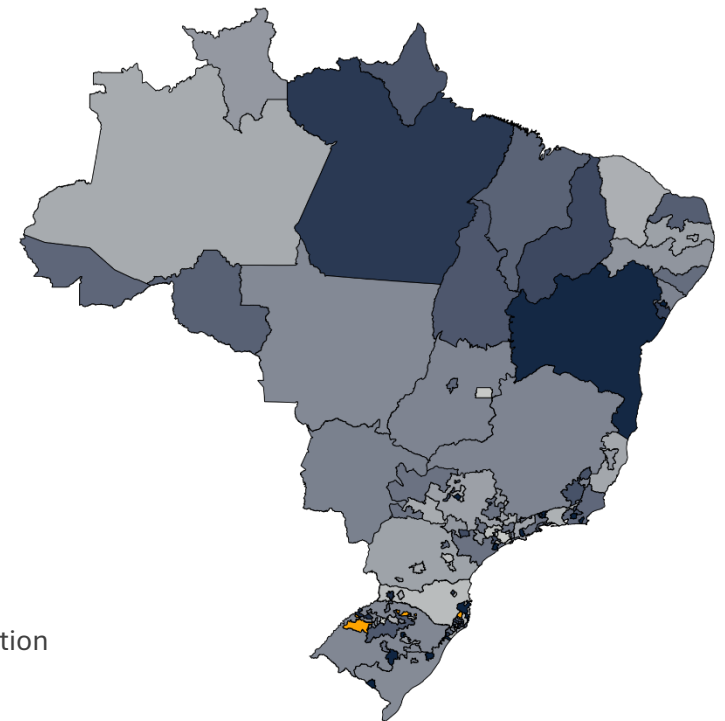
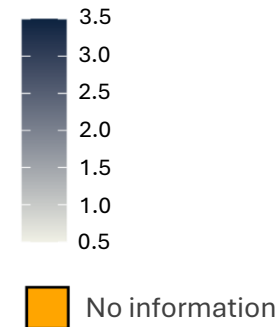
- The map shows the regional variability in the tariff differential between peak and off-peak periods, highlighting areas where the application of energy storage may be more economically advantageous.
- Highest tariff differentials:

Bahia: 3.41 BRL/kWh

Pará: 3.12 BRL/kWh

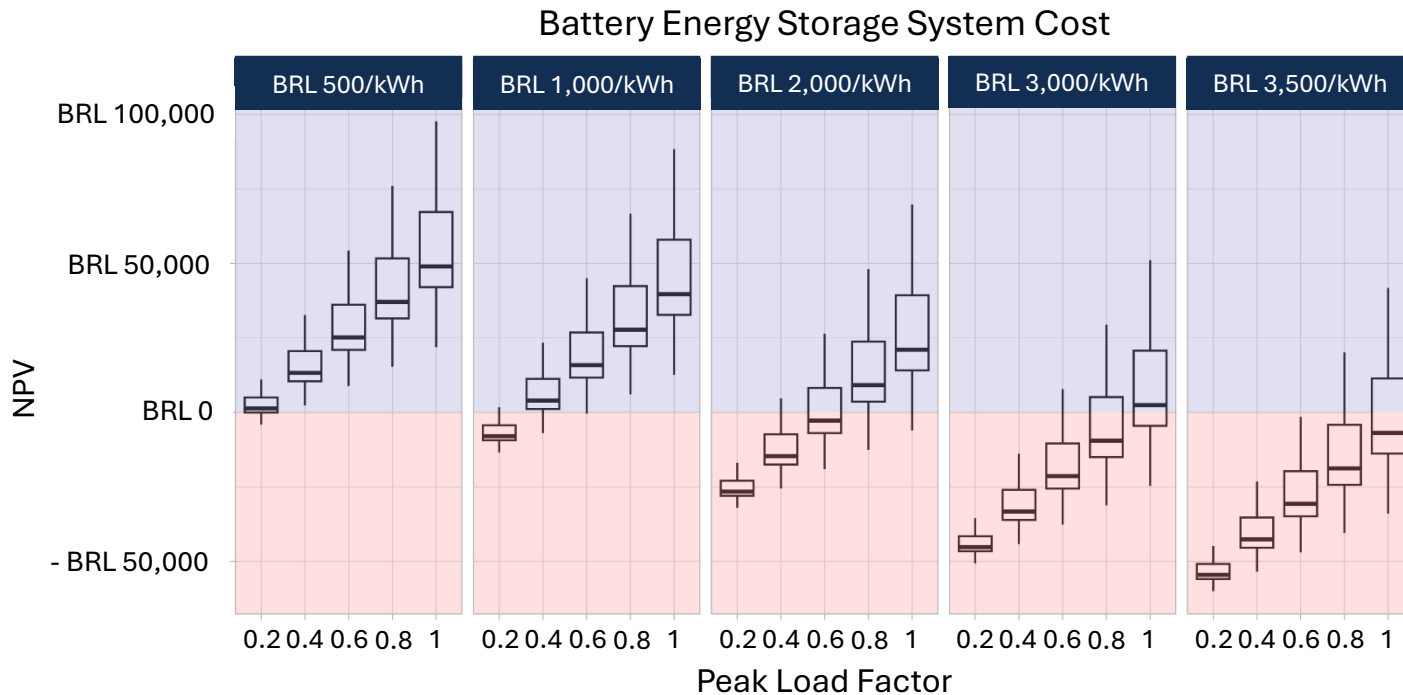
Sergipe: 2.99 BRL/kWh

P - OP Differential  
(BRL/kWh)



# Application I: Consumption management under A4 – Green Tariff

**Net Present Value (NPV) analysis of investments in battery energy storage systems for demand management under the A4 Green tariff scheme: Effects of BESS cost and peak load factor across different distribution utilities.**



## Understanding the Peak Load Factor (PLF)

The annual Peak Load Factor (PLF) expresses the ratio between the average consumption (MW average) and the maximum demand of a user during the peak period (MW).

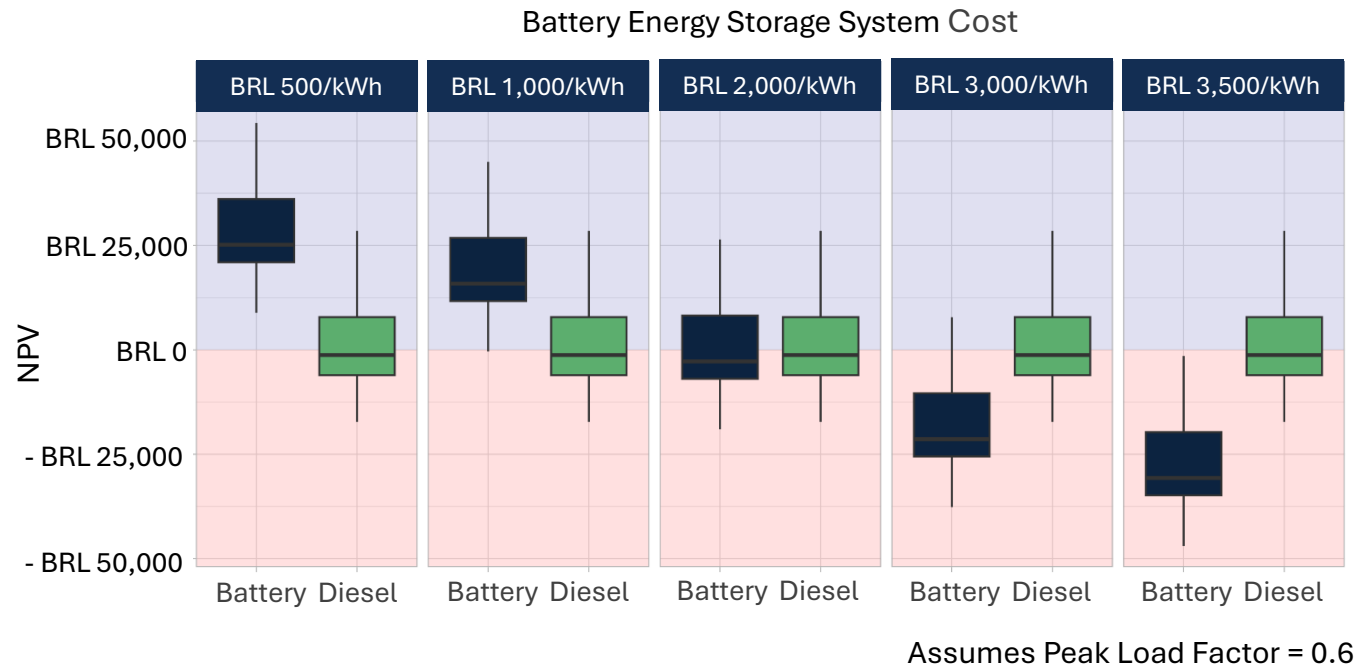
Low PLF values indicate low utilization of the BESS, increasing the payback period of the investment, whereas high PLF values reflect greater stability of the peak consumption profile and, therefore, greater economic feasibility of storage.

- Results show that for consumers with a high PLF, BESS installation may already be economically viable under current tariff conditions in some distribution utilities.

**By exclusively analyzing the option of BTM BESS for peak-hour supply, economic feasibility is observed over the ten-year horizon for consumers with a high peak load factor.**

# Application I compared with diesel generation

**NPV of battery investments compared with diesel generation for consumption management under the A4 Green tariff, as a function of the final BESS price**  
 Analysis for different distribution utilities



- For consumers subject to time-of-use tariffs, BTM BESS can be strategically used to **shift consumption from high-tariff periods** (peak hours) to **lower-cost periods** (off-peak).
- Battery investments start to become competitive at **costs below BRL 2,000/kWh**, compared to diesel generation for supplying peak periods.
- Beyond the economic aspect, additional factors such as **noise reduction, diesel supply logistics, and environmental concerns** can foster the shift from diesel to batteries;
- Moreover, **batteries feature faster response times than diesel generators**, which makes them particularly suitable for critical or sensitive loads, such as hospitals and data centers.

**BTM BESS are already considered competitive alternatives to diesel generation for captive consumers during peak hours. However, the ongoing migration of these consumers to the Free Contracting Environment could limit the potential market for this business model.**

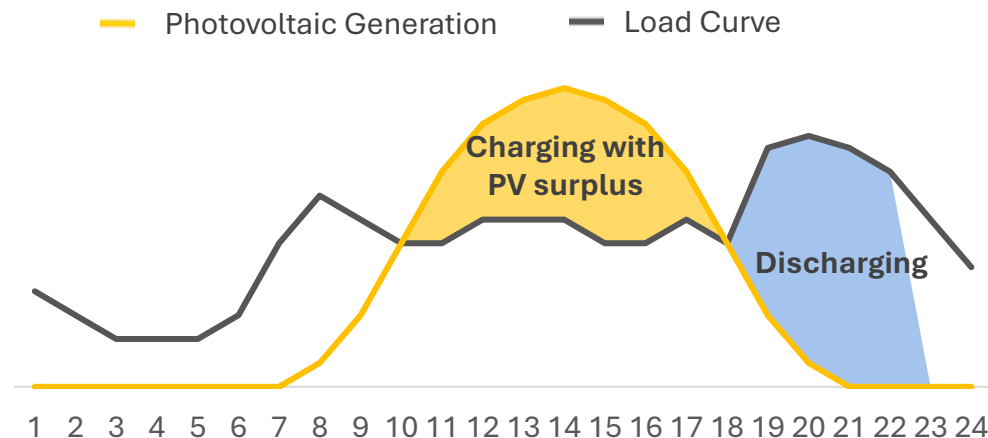
# Application II: Increase of photovoltaic self-consumption in consumers with small-scale distributed generation systems

- Law No. 14,300/2022 amended the Electricity Compensation System, reducing the value of the energy injected into the grid by small-scale distributed generation systems;
- **BTM BESS can be used to avoid grid injection** by storing surplus generation for later consumption;
- Benefits of storing photovoltaic surplus in BTM BESS instead of injecting it into the grid:
  - Capture a greater portion of the generated energy's value;
  - Hedge against potential regulatory changes that could diminish the benefits of the Electricity Compensation System;
  - Shift consumption to off-peak or lower-tariff periods, thereby optimizing electricity cost savings;
  - Enhance resilience at the point of consumption during grid outages.

## Sizing Challenge

The simultaneous variability of photovoltaic generation and load profile makes optimal BESS operation difficult. During periods when production exceeds consumption, the system quickly reaches 100% charge, and the surplus must be exported to the grid. Increasing storage capacity reduces this export but raises CAPEX and results in long intervals of underutilization. **Defining the economic-optimal size therefore requires a detailed cost-benefit analysis and is not a trivial sizing task.**

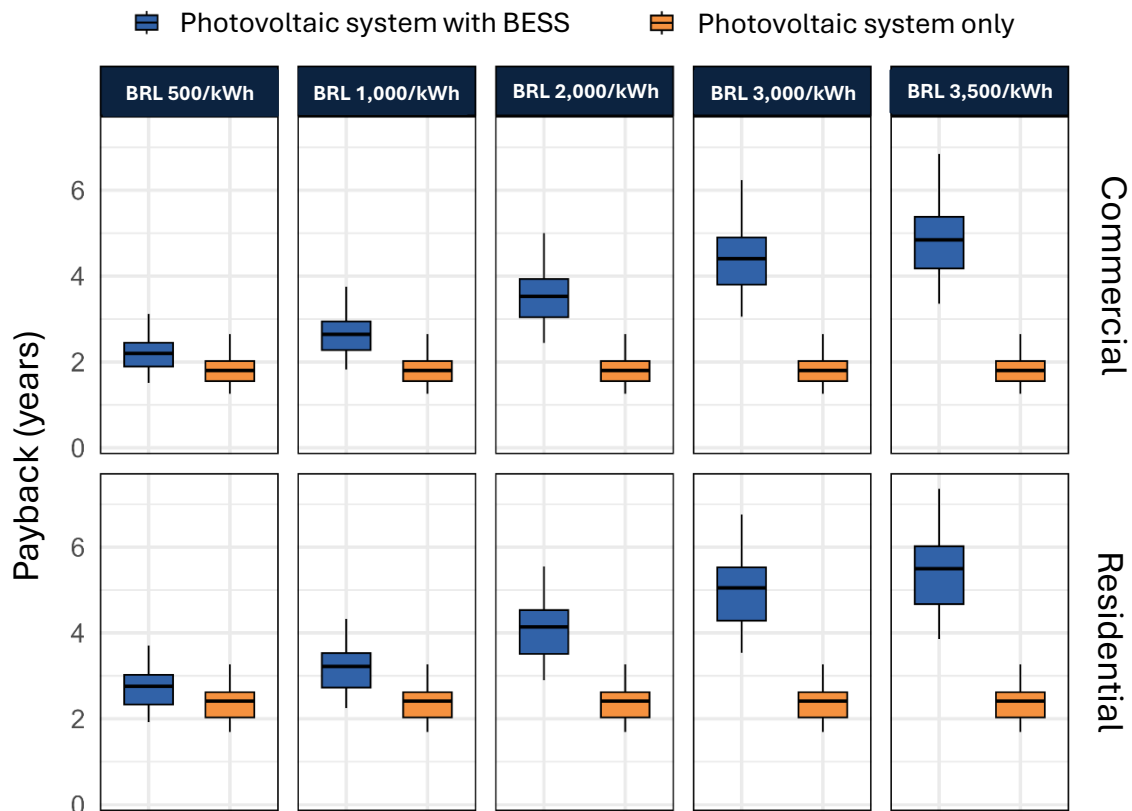
## Illustration of BTM BESS operation for Application II



# Application II: Increase of photovoltaic self-consumption in consumers with small-scale distributed generation systems

## Payback distribution for the purpose of increasing self-consumption of small-scale distributed generation

Analysis for Different Distribution Utilities



Note: This analysis considers the compensation model from the Reference Scenario, as presented in the MMDG section.

The results indicate that the use of BTM BESS extends the investment payback period, reducing its attractiveness. However, **the payback of the PV + BESS may appeal to a niche of consumers over the next decade**, particularly due to its added benefits, such as enhanced electrical resilience.

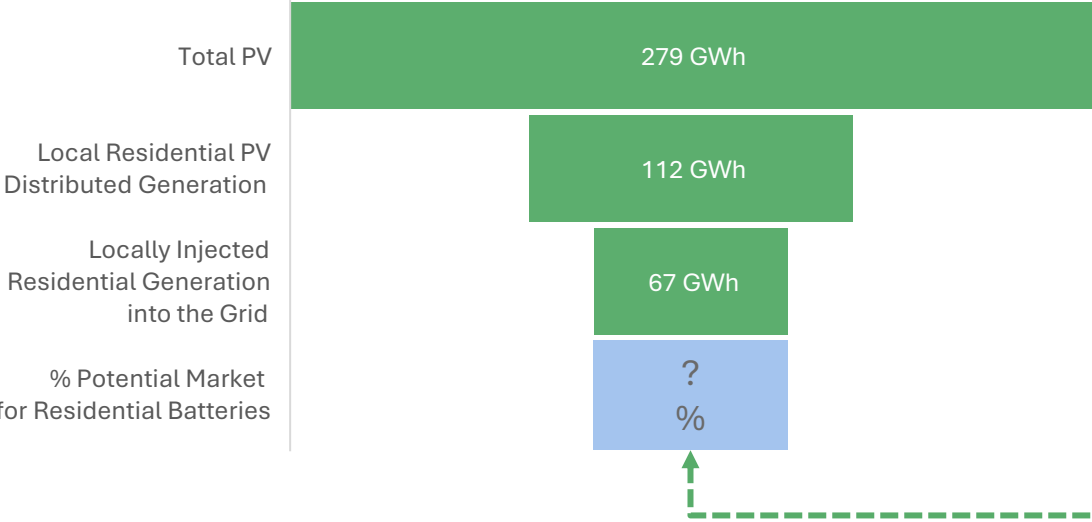
### The Effect of Law No. 14,300/2022 on the Attractiveness of Battery Energy Storage System

- Law No. 14,300/2022 establishes a small and gradual charge on the energy injected into the grid. As a result, **there is limited benefit to be captured** from BESS installation;
- Nevertheless, the expected **cost reduction** of BESS may enhance their attractiveness for end-users;
- This scenario may also change from 2029 onwards, when the **energy injected into the grid** will be valued based on a calculation of its **costs and benefits**. The lower the remuneration for injected DG energy, the greater the viability of battery systems.

# Potential Market for Residential BTM BESS in Brazil

- Based on the projected adoption of photovoltaic systems presented in the previous section, EPE conducted a **preliminary analysis of the investment potential** in BTM BESS for the residential sector;
- The simulation used average daily values to estimate the **investments required** to store fractions of the energy injected by this segment in 2035.

## Potential market (GWh) from the projection of residential PV generation in 2035

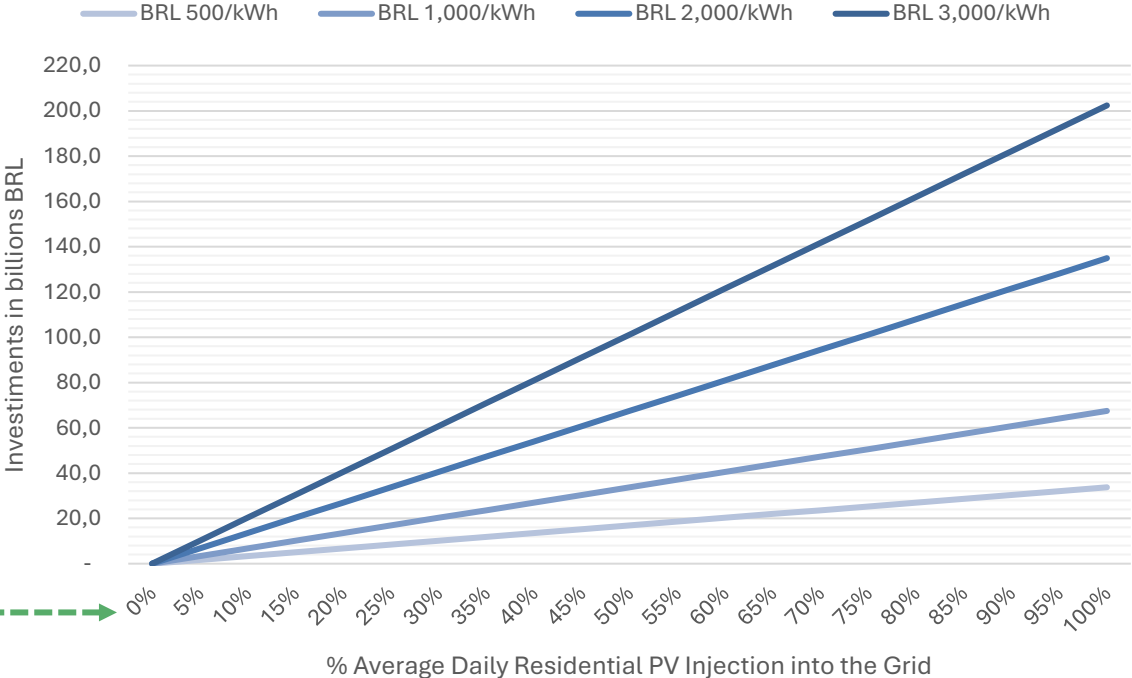


Note: Battery capacity is scaled from the average daily PV generation injected into the grid.

- The sensitivity analysis presented below indicates that investments depend on the degree of market penetration and the unit price of batteries. **Under conditions of maximum market penetration, if all residential consumers with distributed generation (DG) invested in a storage system, and highest BESS prices, cumulative investments could reach approximately BRL 200 billion by 2035.**

## Potential for investments in residential BTM BESS in Brazil

By BESS price in BRL/kWh



# Towards Efficient Integration of Distributed Energy Resources

# New applications for storage systems

As the regulation of energy storage systems advances, new solutions can be envisioned to ensure the efficiency and security of supply in a context of increasing decentralization.

## Aggregators and Virtual Power Plants (VPP)

Aggregators use centralized systems that **control Distributed Energy Resources (DERs) as a single system (VPP)**, optimizing their operation.

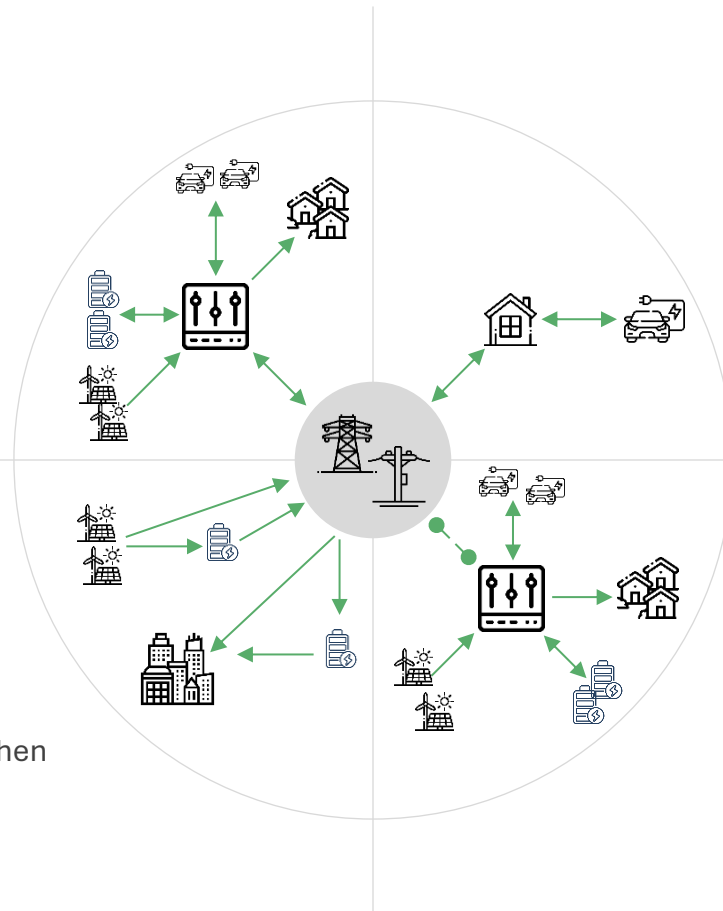
- Local flexibility for distributors
- Balancing services for transmission operators
- Shifting of larger loads

## Virtual Power Lines

**Large grid-connected BESS to meet demand and supply.**

- On the supply side, they store generation surpluses when there are grid constraints
- On the demand side, they charge when grid capacity allows and unload when needed

Source: Adapted from IRENA (2019, 2020)



## Vehicle-to-Grid (V2G)

Allows **electricity to flow from the grid to the electric vehicle and from the vehicle to the grid.**

- Smoothing load and generation variations
- Reduction of vehicle total cost of ownership
  - Consumer load balancing
  - Individual consumer flexibility

## Microgrids

Grids **capable of disconnecting from the main system and running independently** for a period.

- Increased reliability within the microgrid
- Improved power quality within the microgrid
- Renewables within the microgrid operate even with unavailability of the main grid

# Enabling Elements for the Efficient Integration of DERs



## Responsive Tariffs

The current **tariff model** poses a challenge to the efficient integration of Distributed Energy Resources (DERs) in Brazil. Progress toward a framework that provides appropriate economic signals can guide stakeholders' decisions toward achieving **system-wide benefits**.

- A **Tariff Sandbox Governance Pilot Project** is underway, **testing new tariff schemes** applicable to low-voltage consumers;
- ANEEL's Strategic Map foresees the development and implementation of **new tariff models** by 2027.



## Management and aggregation of DERs

With the current level of **diffusion of the MMDG** and the perspective of adopting other **behind-the-meter resources**, the debate on DERs integration and management mechanisms has broadened, with emphasis on aggregators, microgrids and VPPs.

- The topic was discussed within the scope of **ANEEL's Call for Contributions No. 11/2021**;
- Discussion goes through the regulation of **the independent aggregator** and definition of **services provided by DERs** (and their remuneration).



## Active operation of the distribution system

The diffusion of DERs requires a more active role from distributors, becoming the distribution system operator (DSO). This performance enables the **efficient integration** of generation resources in its concession area, **coordinated with the performance of the National Electric System Operator (ONS)**.

- The ONS has been following the **diffusion of MMDG in the National Electric System**, including its representation in load models and load forecasting for energy studies and the study of the **possibilities of interaction with DSOs**;
- ANEEL's regulatory agenda foresees debates on the subject in the **first half of 2026**.

# Uncertainties

## Opening of the Free Energy Market (FEM)

- In September 2022, the Ministry of Mines and Energy (MME) issued Ordinance No. 50, which opened the Free Energy Market to high-voltage consumers. This change is already noticeable, as evidenced by a reduction in the regulated high-voltage market in the Brazilian electricity sector;
- Provisional Measure (MP) No. 1,300/2025, which addresses the reform of the Brazilian electricity sector, includes the **planned opening of the Free Energy Market to all consumers** starting in December 2027;
- With the opening of the Free Market, consumers will have the opportunity to choose alternative electricity suppliers, with the possibility of contracting customized plans that may lead to cost savings.
- In this context, **distributed generation faces a new competitor**, since Free Energy Market consumers are currently not eligible to participate in the net metering system (Article 9, sole paragraph, of Law No. 14,300/2022);

## New Tariff Schemes

- Provisional Measure (MP) No. 1,300/2025 also provides for the implementation of new tariff schemes, such as time-differentiated tariffs, multipart tariffs with capacity charges, locational tariffs, among others;
- If implemented, these new tariff schemes may affect the economic feasibility of distributed generation and energy storage systems.

## Valuation of Costs and Benefits

- Guidelines for valuing the costs and benefits of Distributed Generation (MMDG) were established by CNPE Resolution No. 2/2024. However, **uncertainties remain regarding the tariff applied to energy injected into the grid from 2029 onward**, due to the methodology for calculating MMDG benefits for the electricity sector. This study is included in ANEEL's Regulatory Agenda for the second half of 2026.
- Although the remuneration's effect will start in 2029, **its definition is expected to influence investment decisions throughout the decade**, as it impacts the cash flow of these projects. Similarly, the feasibility of BESS will also be affected, particularly in the context of Application II presented earlier.

# METHODOLOGY (Battery Feasibility Simulations)

- Hourly simulations for one year of operation using the System Advisor Model (SAM) software;
- Hourly load data provided by Sun Mobi through a partnership agreement. After data processing, 15 low-voltage residential and commercial consumers were selected;
- An adjustment factor was applied so that all consumers reached an annual consumption of 10,000 kWh;
- For Application I, peak-hour consumption was modified to simulate different load factors during this period, with a maximum demand of 5 kW;
- Simulations used Lithium Iron Phosphate (LFP) batteries, with a minimum State of Charge (SOC) of 10% and maximum of 100%. Cycle efficiency is 89%, lifespan is 10 years, OPEX is 0.5% of CAPEX per year, and linear degradation reaches 60% capacity after 4,000 cycles with DoD = 90%;
- Real discount rate of 6% per year;
- Electricity tariffs are from December 2024;
- For Application II, hourly photovoltaic generation was simulated using data from cities representative of the utilities. Irradiance and temperature data were sourced from the MERRA-2 reanalysis database.
- Diesel generation was simulated with CAPEX of BRL 1,000/kW, OPEX of R\$25/MWh, diesel price by state in February 2025 (median BRL 5.95/liter), and specific consumption of 329 liters/MWh. Fuel price source: [ANP – Historical price series](#);
- Different configurations of power and storage capacity were tested for each application. The graphs show the configuration with the best average result:
  - Application I: 5 kW / 18 kWh (equivalent to 300 kW / 1080 kWh);
  - Application II: 4 kW / 8 kWh.

# REFERENCES

- ABSAE, 2024. Contribuição para Consulta Pública n. 179 de 11 de dezembro de 2024 para aprimoramento do Plano Decenal de Expansão de Energia 2034 - PDE 2034 e das Diretrizes para o Plano Decenal de Expansão de Energia 2035 - PDE 2035. December 2024.
- ANEEL, 2022. Superintendência de Regulação dos Serviços de Geração. Nota Técnica nº 137/2022-SRG/ANEEL – Consolidação das contribuições recebidas na Tomada de Subsídios nº 011/2020 destinada à obtenção de subsídios para elaboração de propostas de adequações regulatórias necessárias à inserção de sistemas de armazenamento no Sistema Interligado Nacional (SIN). Brasília, DF. November 29, 2022.
- BloombergNEF, 2024. Lithium-Ion Battery Pack Prices See Largest Drop Since 2017, Falling to \$115 per Kilowatt-Hour. December 10, 2024. Available at: <https://about.bnef.com/insights/commodities/lithium-ion-battery-pack-prices-see-largest-drop-since-2017-falling-to-115-per-kilowatt-hour-bloombergnef/>. Accessed on: May 31, 2025.
- BloombergNEF, 2025. Brazil Transition Factbook. Abril de 2025. Available at: <https://assets.bbhub.io/professional/sites/24/Brazil-Transition-Factbook-2025.pdf>. Accessed on: May 31, 2025.
- EPE, 2015. Estimativa da Capacidade Instalada de Geração Distribuída no SIN: Aplicações no Horário de Ponta. February 2015.
- EPE, 2018. Recursos Energéticos Distribuídos: Impactos no Planejamento Energético. June 2018.
- Greener, 2025a. Estudo Estratégico 2025. Armazenamento de Energia: Setor Elétrico Brasileiro. Sample version. February 2025.
- Greener, 2025b. Estudo Estratégico Referente ao ano de 2024. Geração Distribuída: Mercado Fotovoltaico. March 2025.
- IEA, 2024. Batteries and Secure Energy Transitions. April 2024.
- IRENA, 2019. Innovation landscape brief: Aggregators. 2019.
- IRENA, 2020. Virtual power lines. Innovation Landscape Brief. 2020.
- INMETRO, 2025. Sistemas e equipamentos para energia fotovoltaica (módulo, controlador de carga, inversor e bateria). Catalogued since: September 3, 2019. Available at: <https://dados.gov.br/dados/conjuntos-dados/registro-de-objetos>. Accessed on: March 12, 2025.



**PDE** 2035

Follow EPE in social media and digital platforms:



MINISTÉRIO DE  
MINAS E ENERGIA

