How variable and distributed energy resources are reshaping the challenges of planning and operating of the Brazilian Interconnected Power System

Great Place To Work® Certificada Dez/2025 - Dez/2026 BRASIL

ONS Operador Nacional do Sistema Elétrico

August 20, 2026

Roles of Brazilian Electricity Sector Institutions

Power system operation

ONS Operador Nacional do Sistema Elétrico

Regulatory agency

ANEEL Agência Nacional de Energia Elétrica

Market operation

ccee Câmara de Comercialização de Energia Elétrica

Long –term transmission and generation expansion planning

epe Empresa de Pesquisa Energética

ONS Operador Nacional do Sistema Elétrico

LEGAL STRUCTURE

Article 13 of Law No. 9,648/98

(as amended by Law No. 10,848/04), regulated by Decree No. 5,081/04.

About

A private, non-profit legal entity regulated and supervised by ANEEL (Brazilian Electricity Regulatory Agency).

ONS does not own any energy generation, transmission or distribution assets.

Centralized management of BIPS (Brazilian Interconnected Power System) operations ensures secure operation at the lowest possible cost.

Mission

To ensure a reliable supply of electricity across the country, with quality and a balance between security and overall cost.

ONS in numbers

4 Regional centers

1 National center

24/7

1087 Employees

As of July/26

Brazilian Interconnected Power System (BIPS)

Brazilian Interconnected Power System

Extension of transmission lines* ≥ 230 kV:

2026: 181,326 km

2030: 196,160 km (expected)

ONS operates one of the world's largest renewable power systems, creating unique operational challenges

Energy load

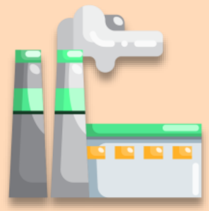
Peak: 106,536 MW February 26, 2025, at 2:45PM

Renewable Energy Record | February 26, 2025

Load supplied by

93.4%

renewable energy (90.1 GWmed)

109.7 GW | 40.8%	31.9 GW | 11.9%	33.7 GW | 12.5%	21.2 GW | 7.9%	2.0 GW | 0.7%	50.9 GW | 18.9%	19.5 GW | 7.2%
						
HYDRO	THERMAL	WIND	SOLAR	NUCLEAR	DPV	DG (Type III)

Installed and Expected Capacity

2026 – 268.9 GW | 2031 – 318.5 GW

Hydro
Installed: 109.7 GW
Expected: 109.7 GW
0%

Thermal
Installed: 33.9 GW
Expected: 37.9 GW
12.0%
4.1 GW

DG (Type III)
Installed: 19.5 GW
Expected: 20.3 GW
4.2%
0.8 GW

Wind
Installed: 33.7 GW
Expected: 38.9 GW
15.5%
5.2 GW

Solar
Installed: 21.2 GW
Expected: 38.7 GW
82.0%
17.4 GW

DPV
Installed: 50.9 GW
Expected: 73.0 GW
43.4%
22.1 GW

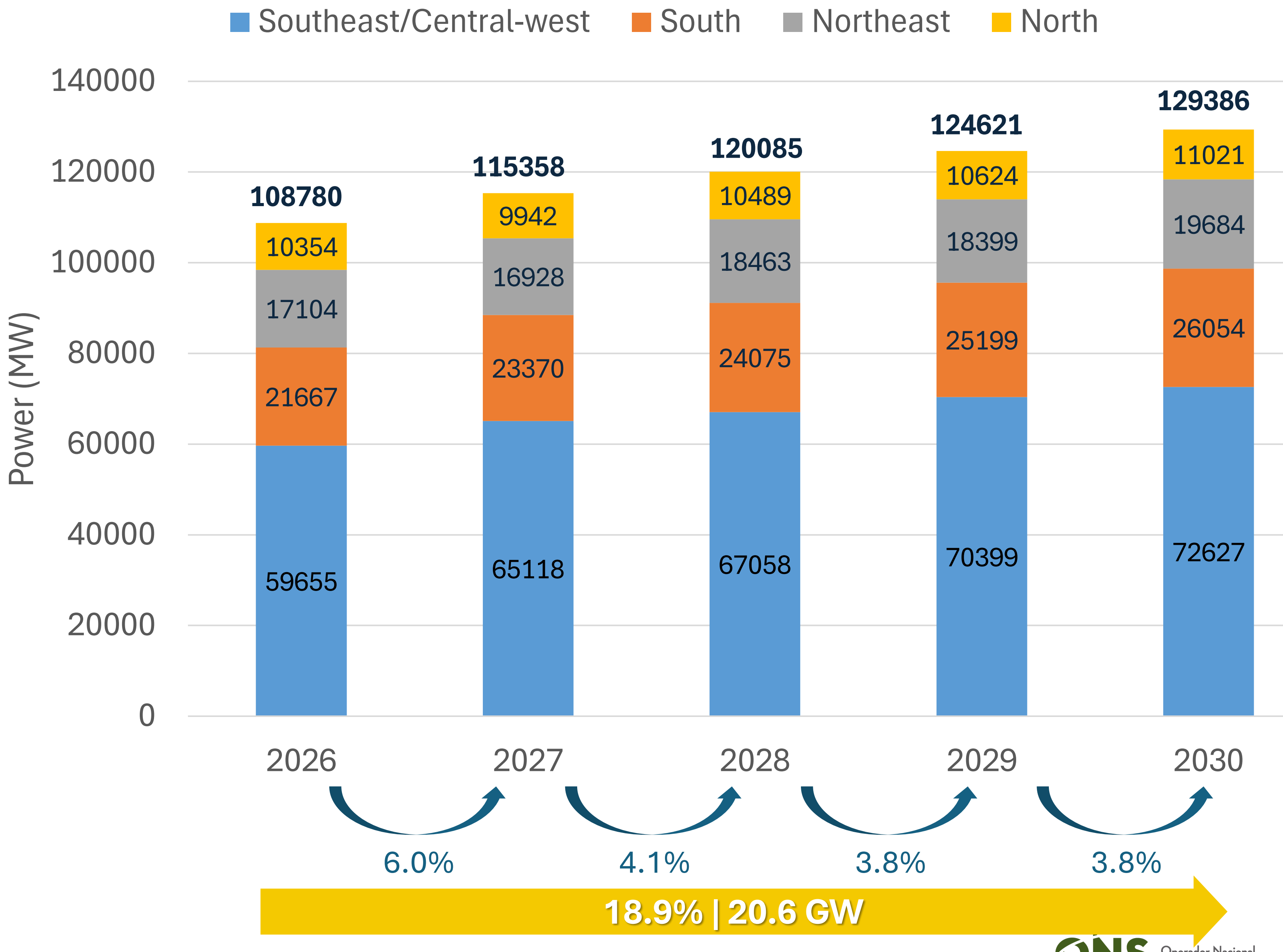
Brazil's future capacity growth will be driven by inverter-based resources, mainly centralized and distributed solar generation

Source: ONS Website / Aug, 2026

Peak Load Forecasting

Demand is growing, but much slower than DPV and IBRs generation capacity

This increasing gap between generation and demand is creating new operational challenges during daytime hours

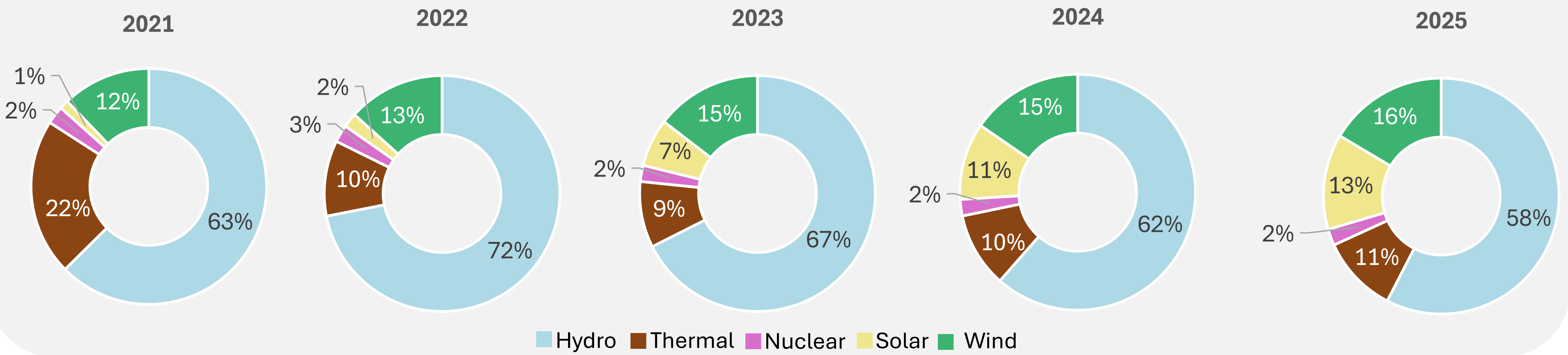


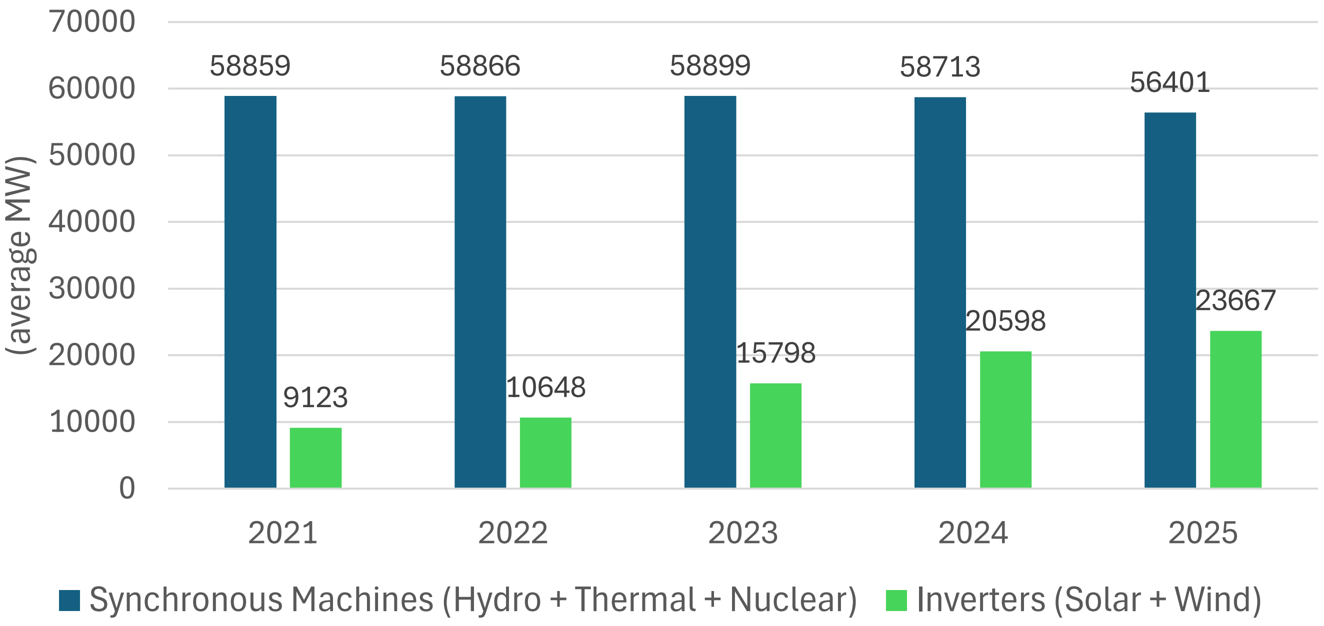
Source: Energy Operation Plan 2026 - ONS

ONS Operador Nacional do Sistema Elétrico

Evolution of the BIPS Electricity Supply Mix

Generated Energy (average MW)





Rapid growth of inverter-based resources (IBRs)

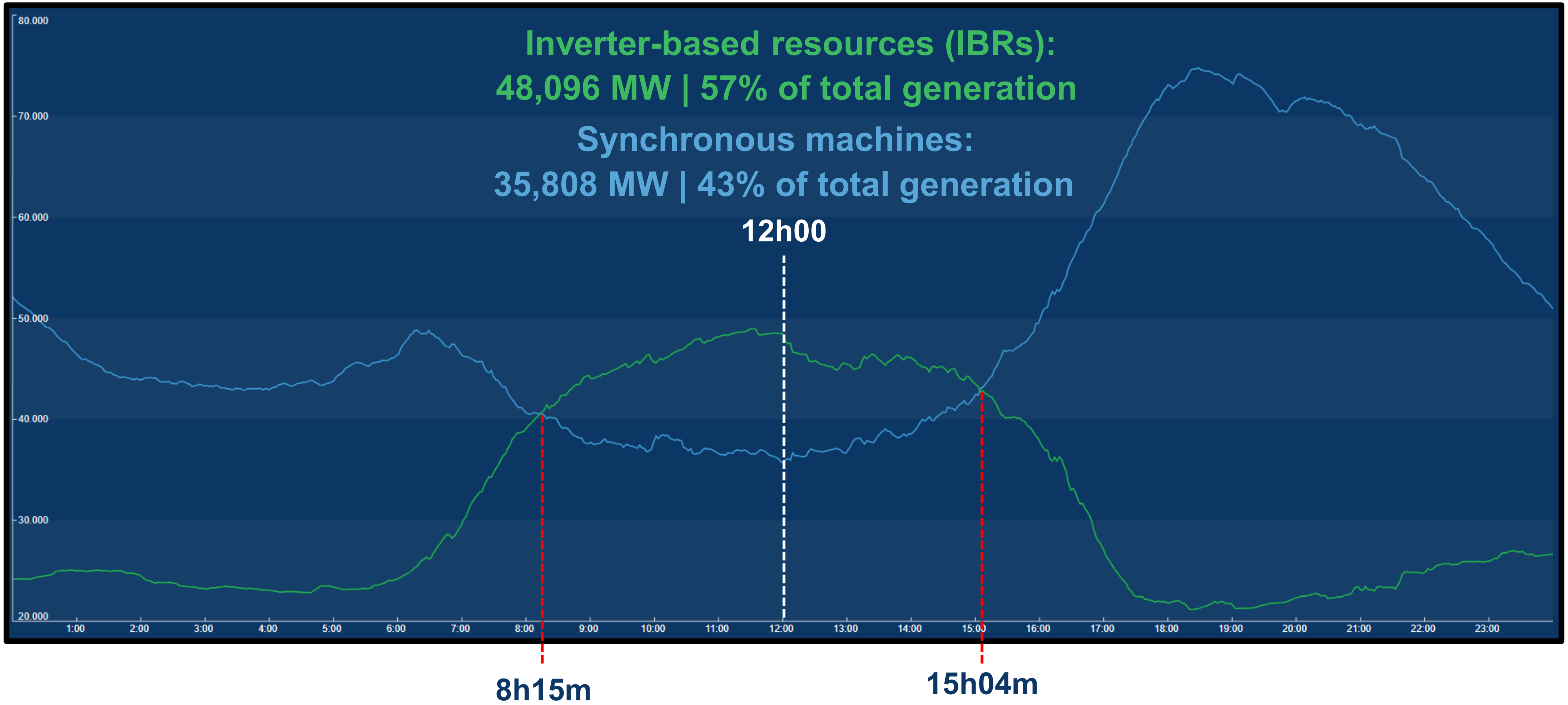
How the generation mix has changed (2021–2025)

- **Synchronous machines: 4% decrease**
- **Inverters: 159% increase**

Less synchronous generation and more IBRs means new operational challenges

Synchronous Machines *x* IBRs

July 1, 2026 (Wednesday)

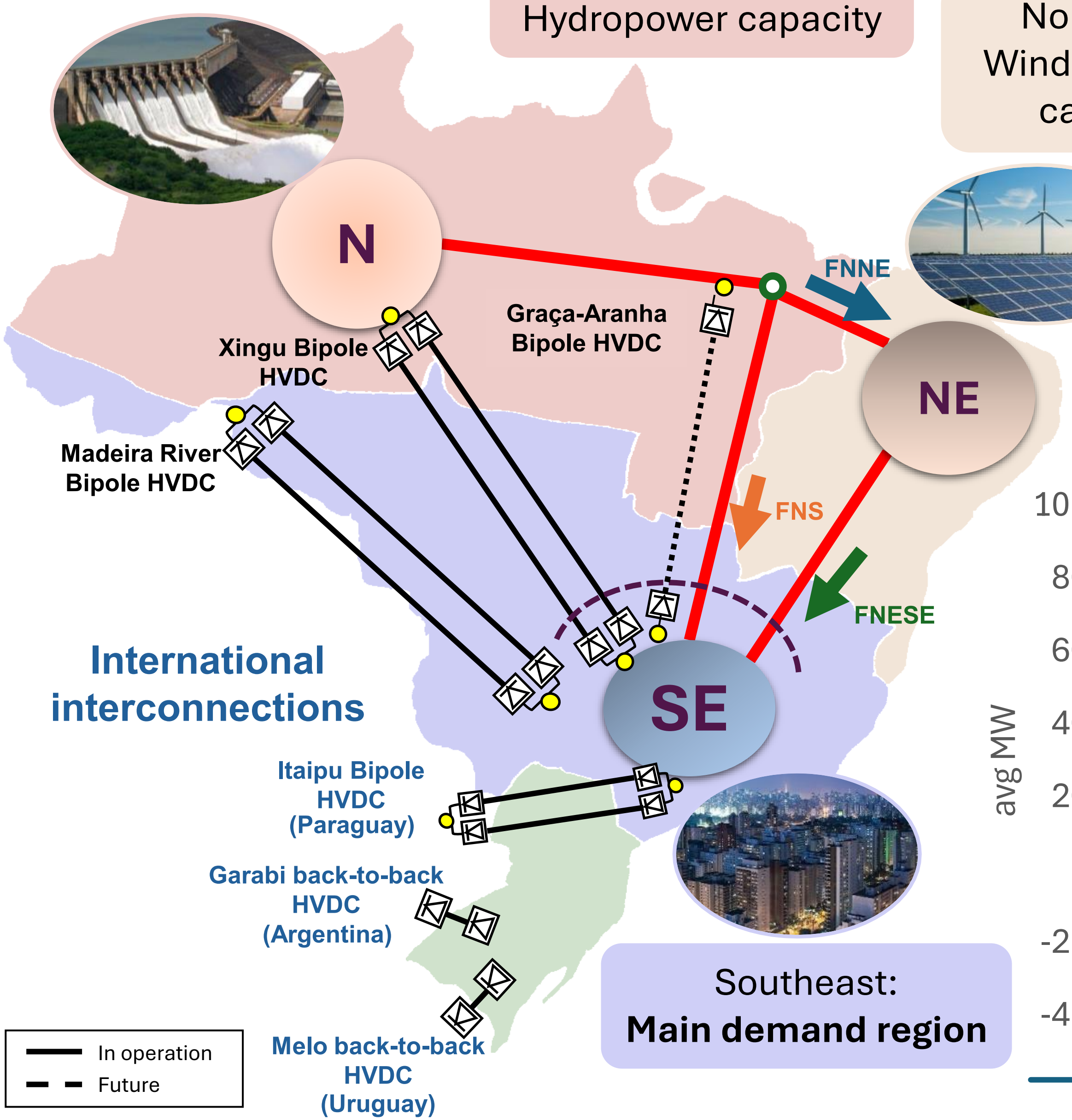


New operational reality:
IBR generation exceeds synchronous generation during daylight hours

Regional Interconnections

North:
Hydropower capacity

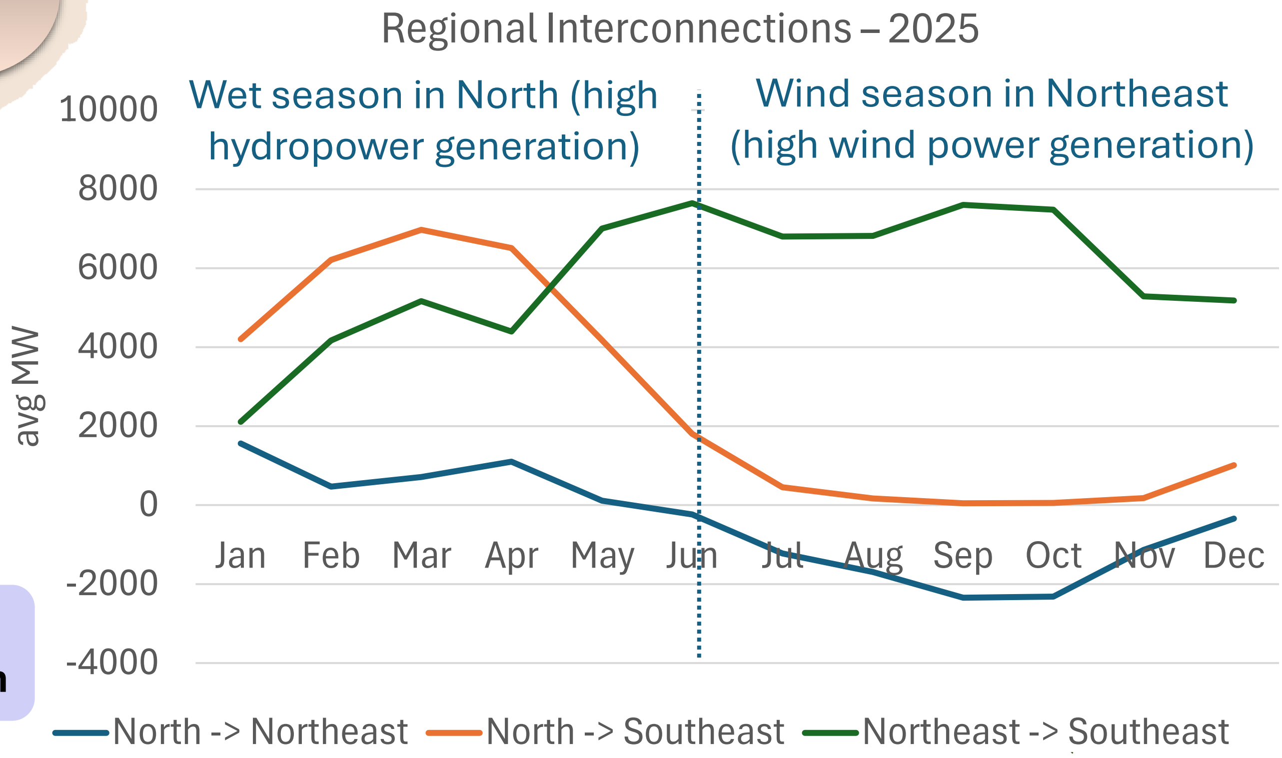
Northeast:
Wind and solar capacity



Southeast:
Main demand region

Most common operating scenario: Power flows from the North and Northeast to the Southeast

- FNNE: North -> Northeast;
- FNS: North -> Southeast;
- FNESE: Northeast -> Southeast.



Curtailment in Brazil: from a one-off phenomenon to a structural challenge

Evolution of Renewable Curtailment

(% of generation potential)

August 15, 2023 Blackout

- ✓ ONS identified a discrepancy between information provided by agents and actual on-site conditions;
- ✓ ONS revised its database and reassessed power transfer limits, improving consistency between operational data and actual grid conditions.

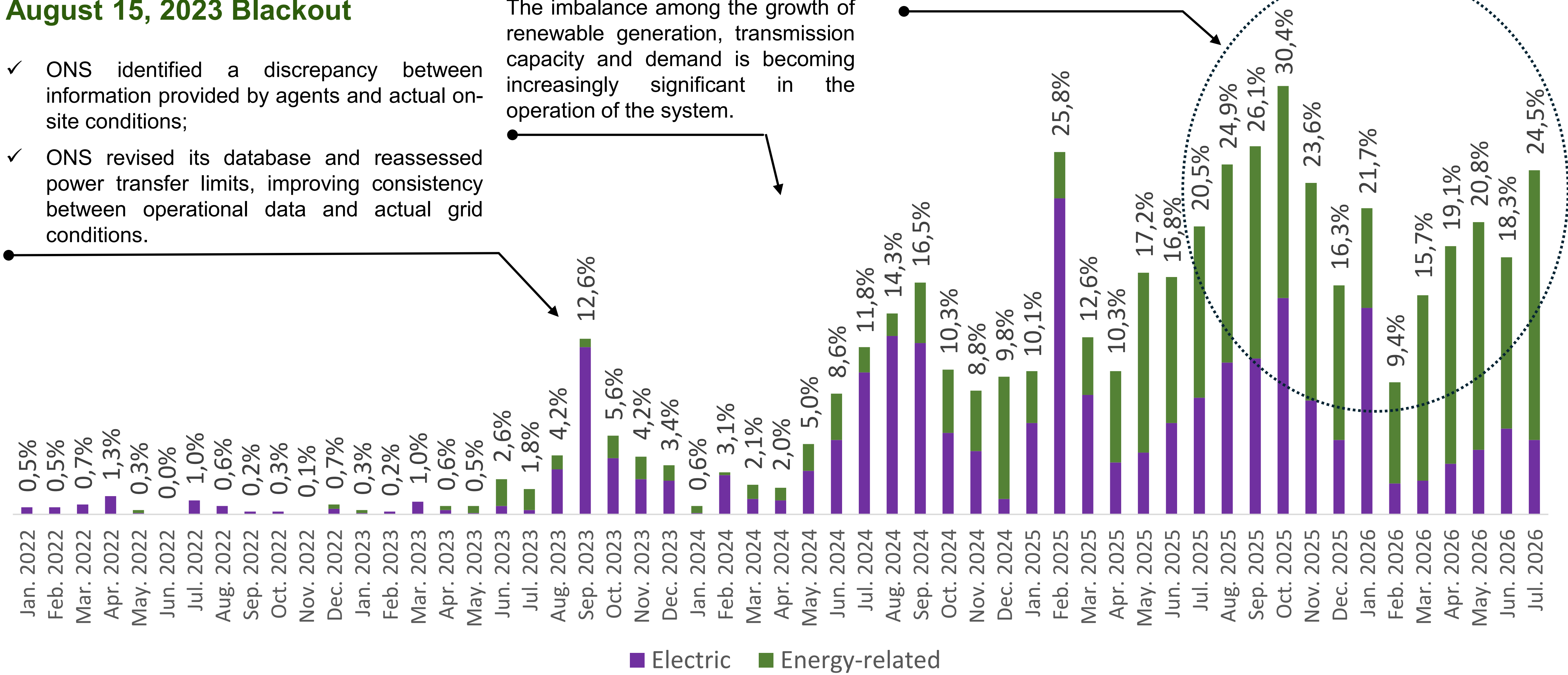
From 2024 on

The imbalance among the growth of renewable generation, transmission capacity and demand is becoming increasingly significant in the operation of the system.

Distributed Generation (DG)

Distributed solar generation has reduced the daytime net load, increasing the need for renewable curtailment.

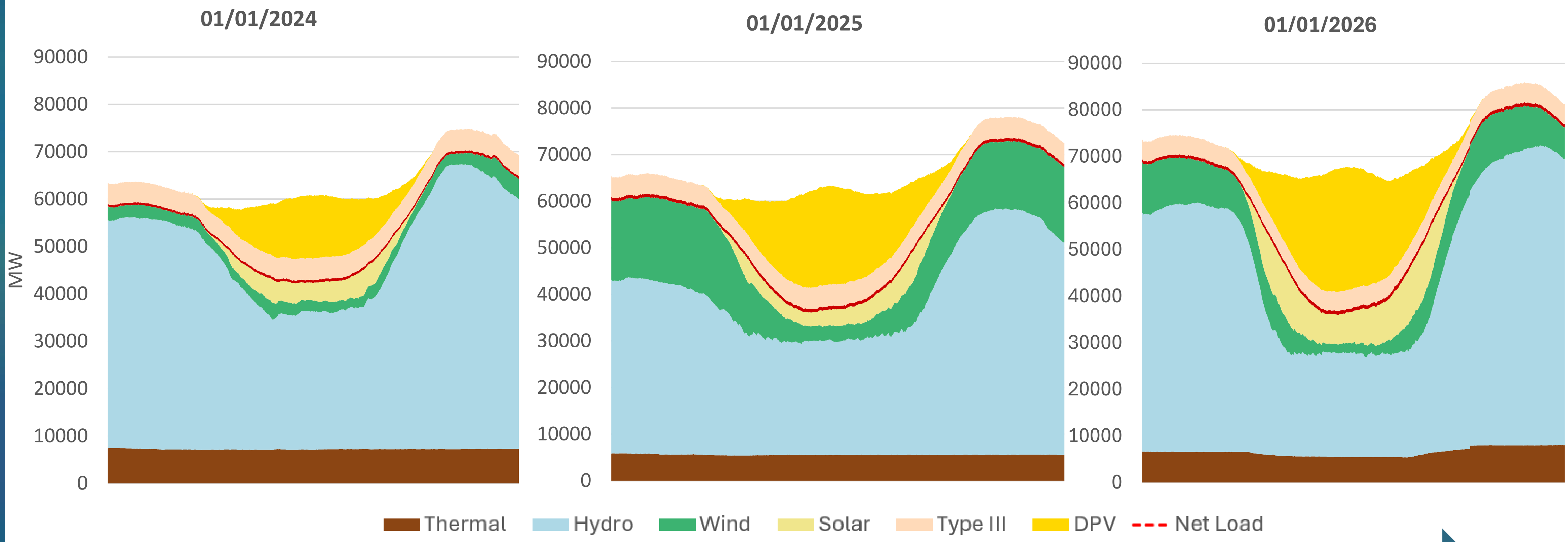
Increasing energy curtailment



The operational paradigm of the Brazilian power system is gradually shifting from mitigating transmission constraints to efficiently managing generation surplus

ONS Operador Nacional do Sistema Elétrico

How DG Penetration is Reshaping Daily System Operation



As distributed generation grows, it supplies a larger share of the daytime demand

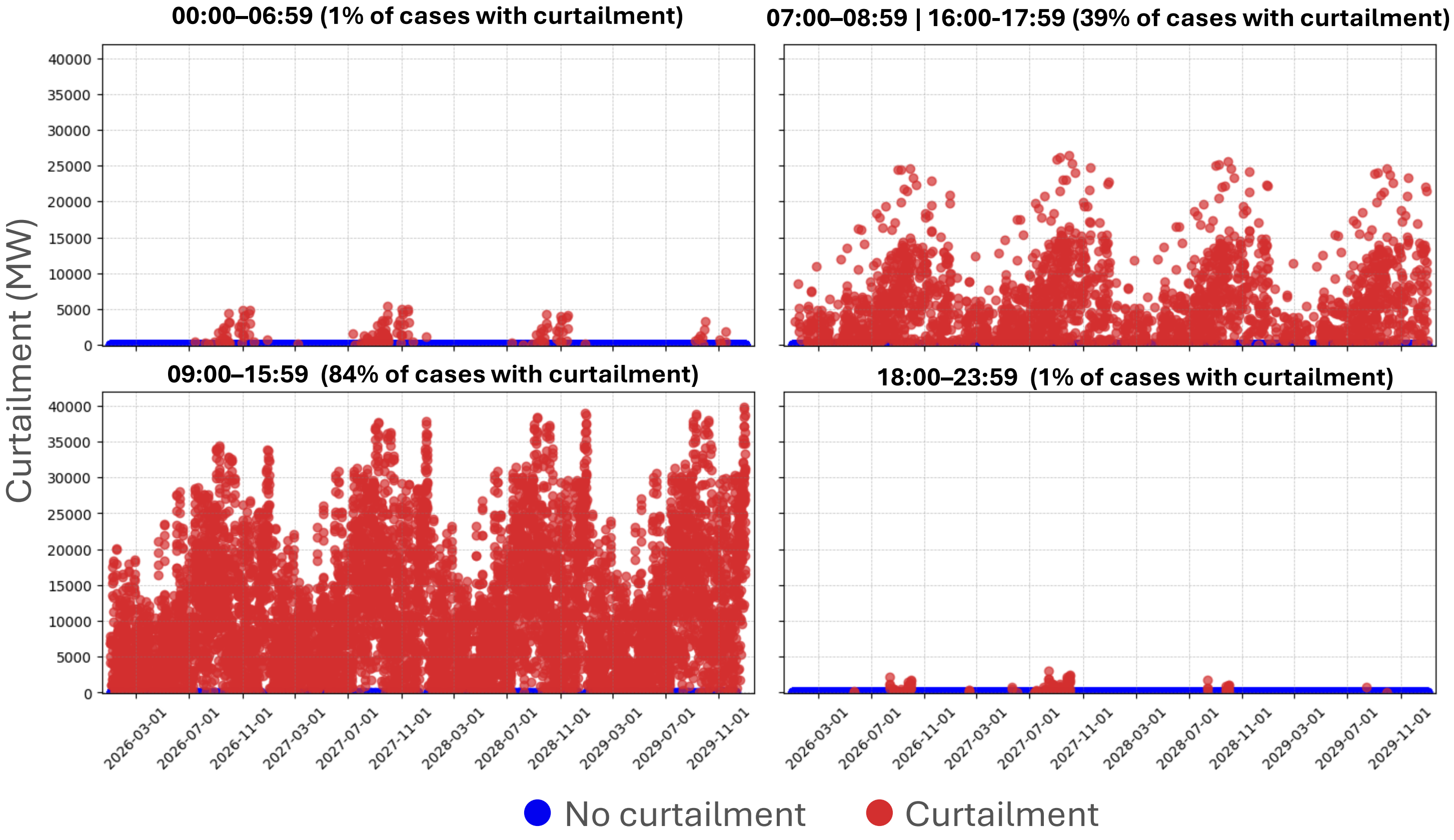
- The fast expansion of distributed generation (mainly rooftop solar) is **displacing centralized resources** during the day, deepening the **midday generation valley** and causing **more frequent generation curtailment**.
- The **growing operational complexity** is due to the increasing penetration of variable renewable sources, with a growing need for **flexibility** to keep the system balance.

ONS Operador Nacional do Sistema Elétrico

Curtailment Scenario Until 2029

OPERATIONAL PLANNING 2026-2029

- Increased curtailment associated with the high share of variable centralized and distributed renewable generation during daytime hours.
- Excess supply is the main cause of curtailment.
- Curtailment could exceed 40 GW in the most critical scenarios.



Curtailment caused by energy-related issues is expected to remain a structural challenge

Curtailment is highly concentrated during daylight hours (09:00 – 15:59)

ONS Operador Nacional do Sistema Elétrico

Key Factors Driving the Increase in Curtailment

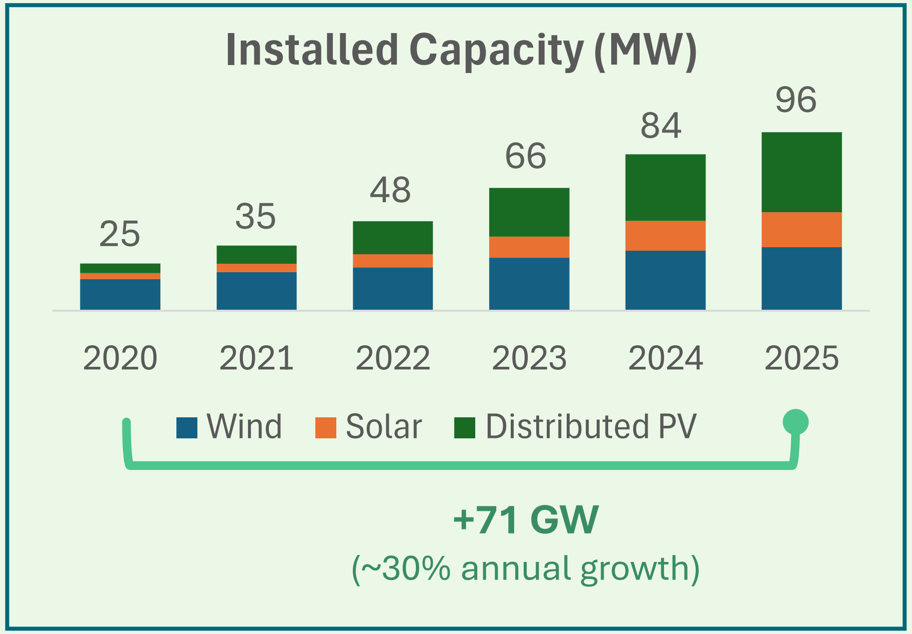
The imbalance between the growth of renewable generation and energy demand

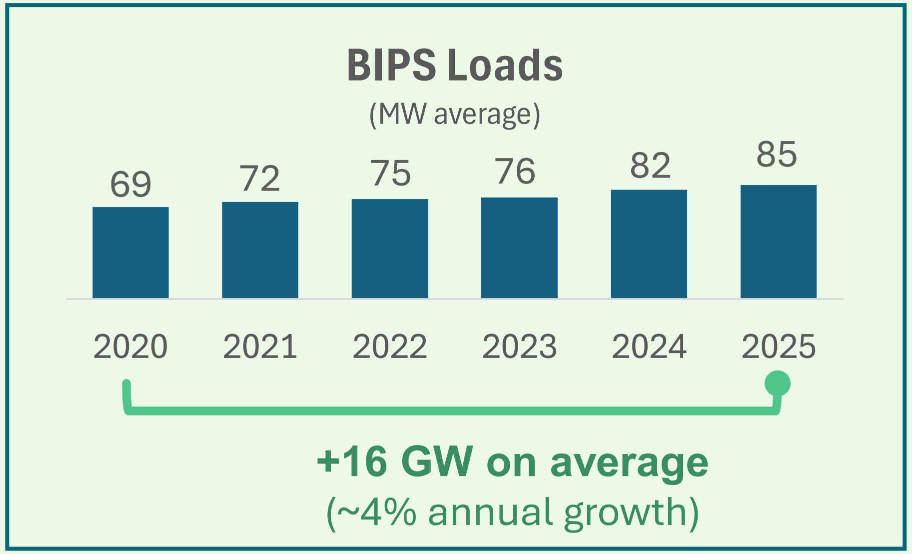
Renewable generation is growing **faster than energy demand**.

Renewable energy generation is growing **faster than the expansion of the power grid.**

Rapid growth in solar power generation, concentrated between 9 a.m. and 4 p.m.

Curtailment does not apply to distributed generation (DG). Only centrally dispatched power plants are reduced.





Operador Nacional do Sistema Elétrico

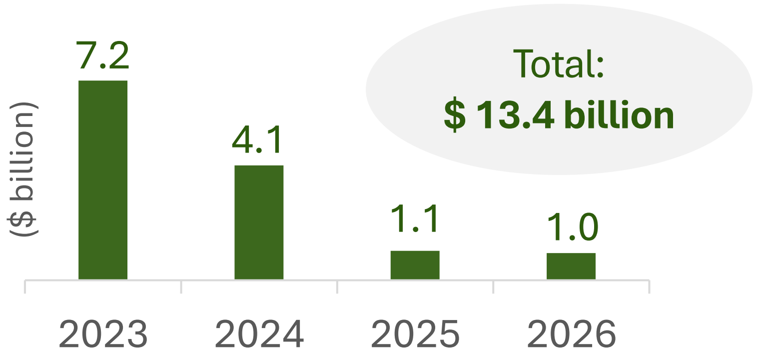
Measures to Reduce Curtailment

Expansion of the transmission system

Deployment and implementation of **Special Protection Systems** (SPS) – a tool that prevents blackouts and preserves the power system stability in critical situations related to generation flow, thereby enabling the integration of transmission projects planned for the coming years.

Implementation of new transmission lines, substations and synchronous condensers.

Investments in transmission expansion:



Evolution of interregional **interconnection limits**:

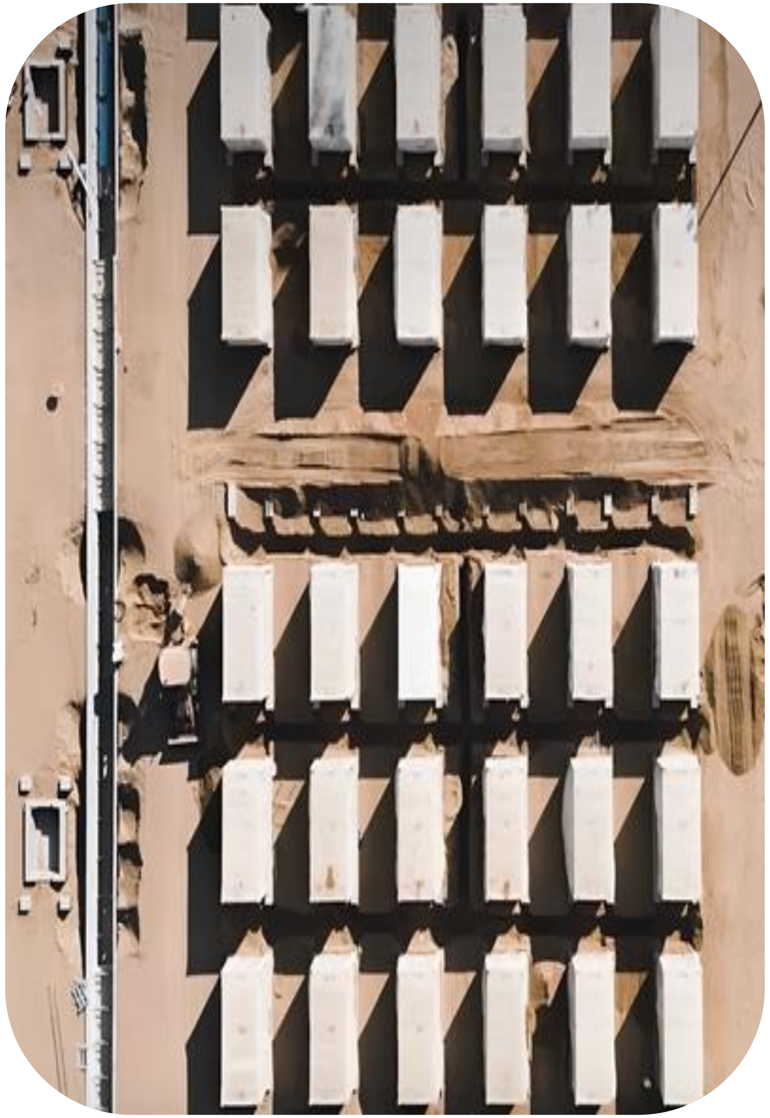
An increase of approximately 25% in the capacity limit for power flows from the North/Northeast to the Southeast/Midwest, rising from 18,500 MW to 23,000 MW in 2030;

An increase of approximately 20% in the capacity limit for power received by the South from the Southeast/Midwest, rising from 11,400 MW to 13,500 MW in 2030.

Progress is being made on the construction of the **Graça Aranha – Silvânia HVDC bipole**, which is scheduled for completion in 2028. This project will expand energy exchange between the North/Northeast and Southeast/Midwest regions. The bipole has a capacity of 5,000 MW.

Measures to Reduce Curtailment

Advances in energy storage systems and integration of energy-intensive loads



Increasing flexibility is the key to reducing future curtailment for energy reasons

- The Ten-Year Energy Expansion Plan, prepared by the Energy Research Company (EPE), and covering the period through 2035, estimates that energy storage capacity will increase by 6,631 MW by 2035. This increase will be largely driven by battery storage.
- Regulations on battery storage systems are under review by Brazil's Electricity Regulatory Agency (ANEEL). At the same time, ONS is evaluating the technical requirements for grid connection.
- The Ministry of Mines and Energy (MME) will hold Brazil's first Energy Storage Capacity Auction in December 2026. The auction will procure firm capacity from battery energy storage systems (BESS) to enhance power system reliability during peak demand periods and help reduce renewable energy curtailment.
- The integration of electricity-intensive loads, such as data centers and hydrogen plants, also contributes to reducing curtailment.

Considerations

The **daytime period** will account for the largest share of generation curtailments, mainly due to the **high volume of wind, solar and distributed generation in the** Brazilian Interconnected Power System.

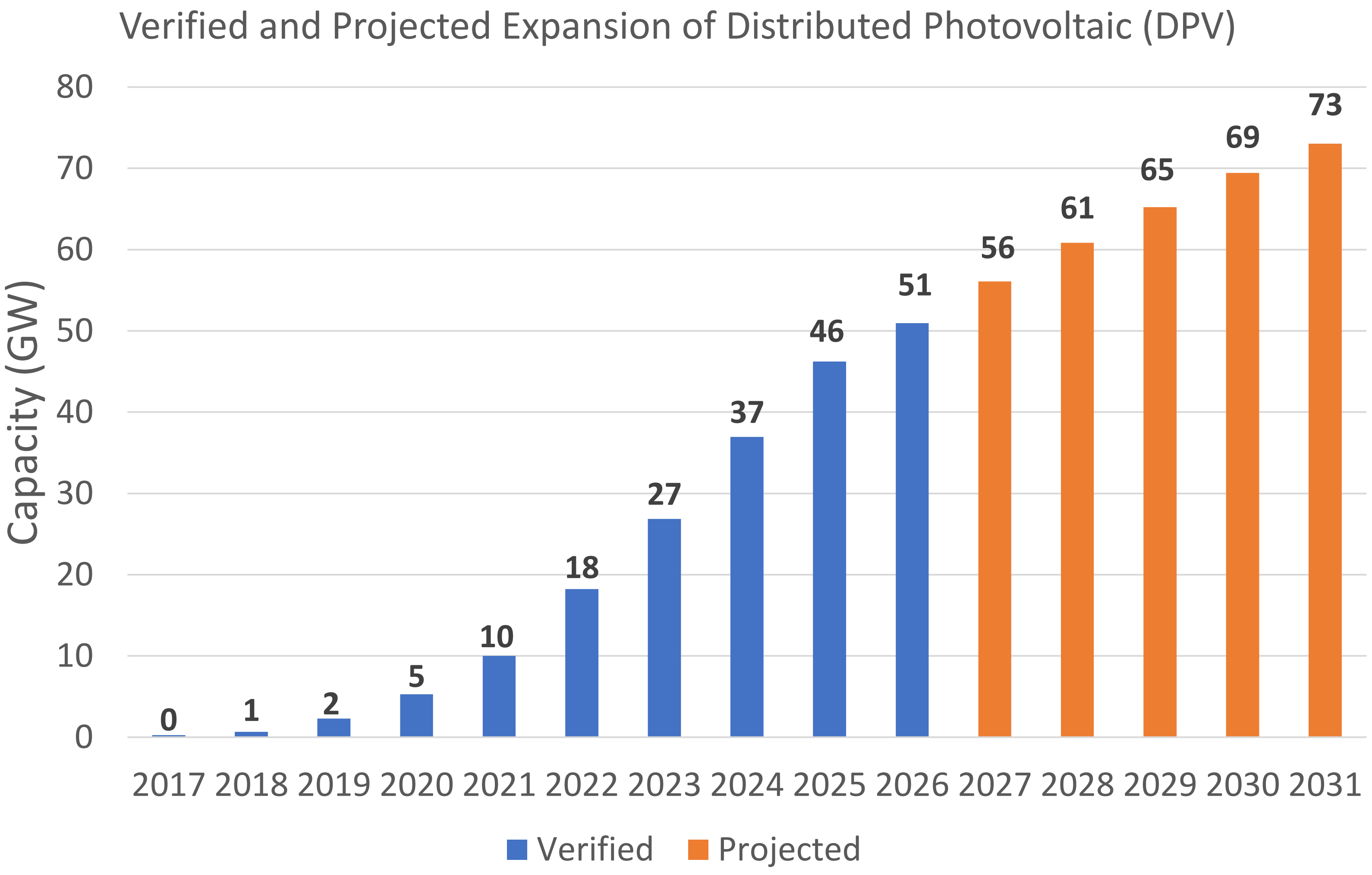
Curtailment caused by **energy-related issues** will be **more common than those caused by reliability issues,** given the expansion of the transmission system.

A **reduction** in curtailment will depend not only on the **expansion of transmission capacity**, the **integration of large consumers**, or **flexibility resources** such as storage or demand response, but rather on an **integrated set of convergent and structural measures**.

There is a need to **rationalize public policies, incentives, and subsidies** so that the future expansion of supply, particularly **solar power (both centralized and distributed)**, does not continue to outpace the **growth of the power system daytime load**.

Impacts of Distributed Generation on System Operation

Distributed Generation in the Brazilian Interconnected Power System



Current Scenario

+ ≈ 20 GW from type III generation

≈ 71 GW from Distributed Generation (DG)

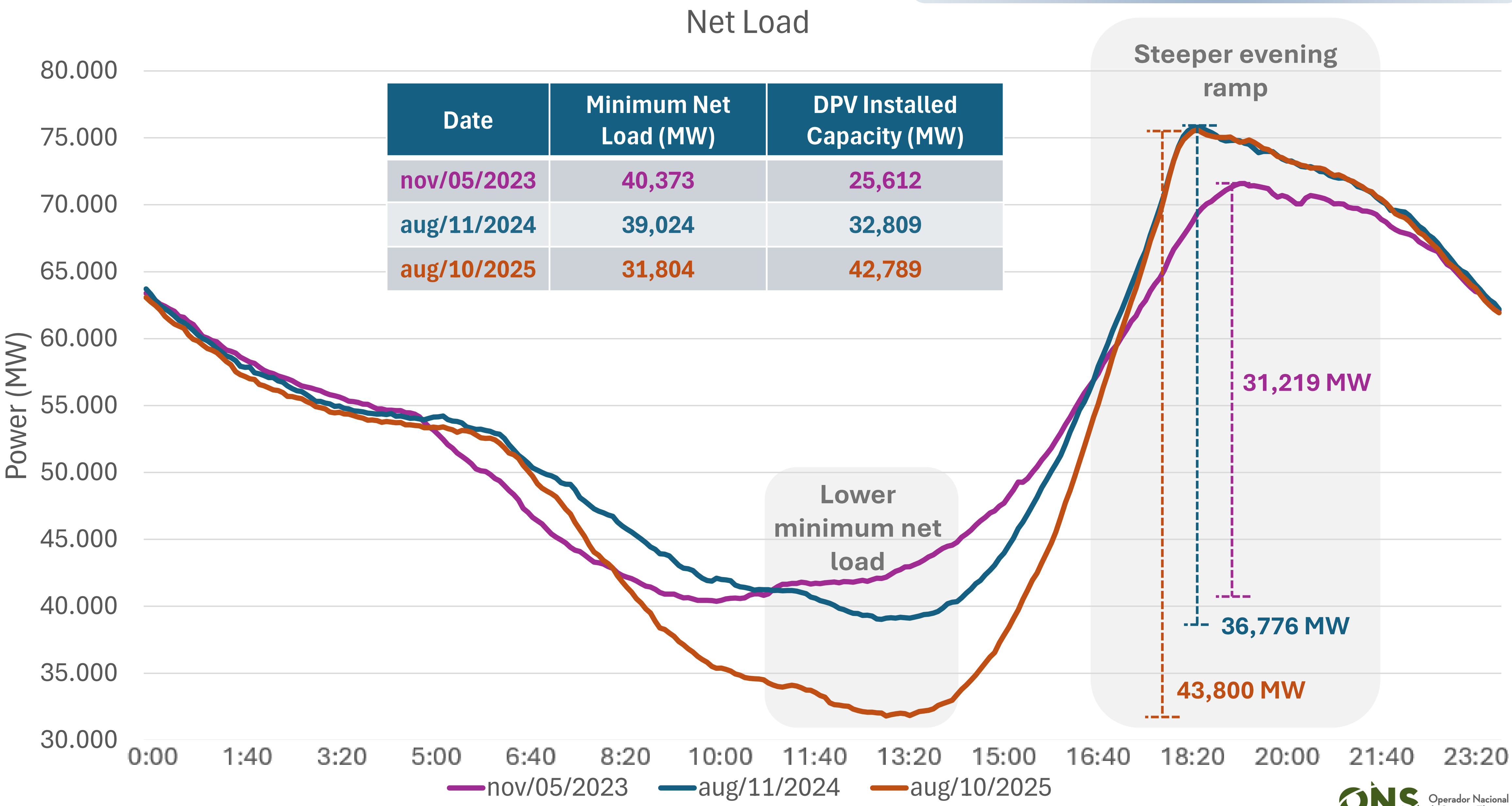
Peak Load in Brazil ≈ 106 GW

Distributed generation is no longer a small resource. It has become a major part of the Brazilian power system

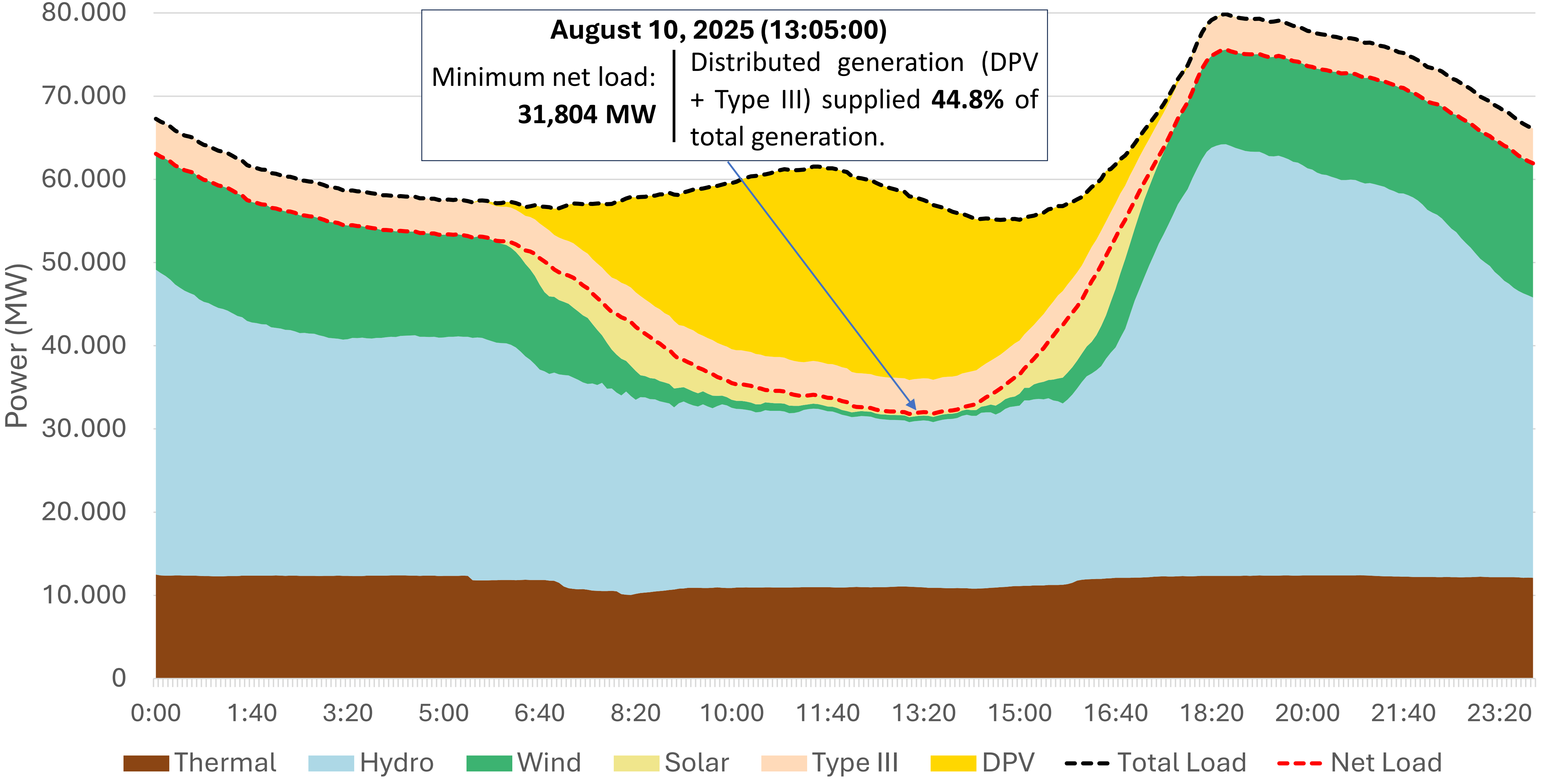
Minimum Net Load Curves

DG is creating deeper midday valleys and steeper evening ramps

Date	Minimum Net Load (MW)	DPV Installed Capacity (MW)
nov/05/2023	40,373	25,612
aug/11/2024	39,024	32,809
aug/10/2025	31,804	42,789

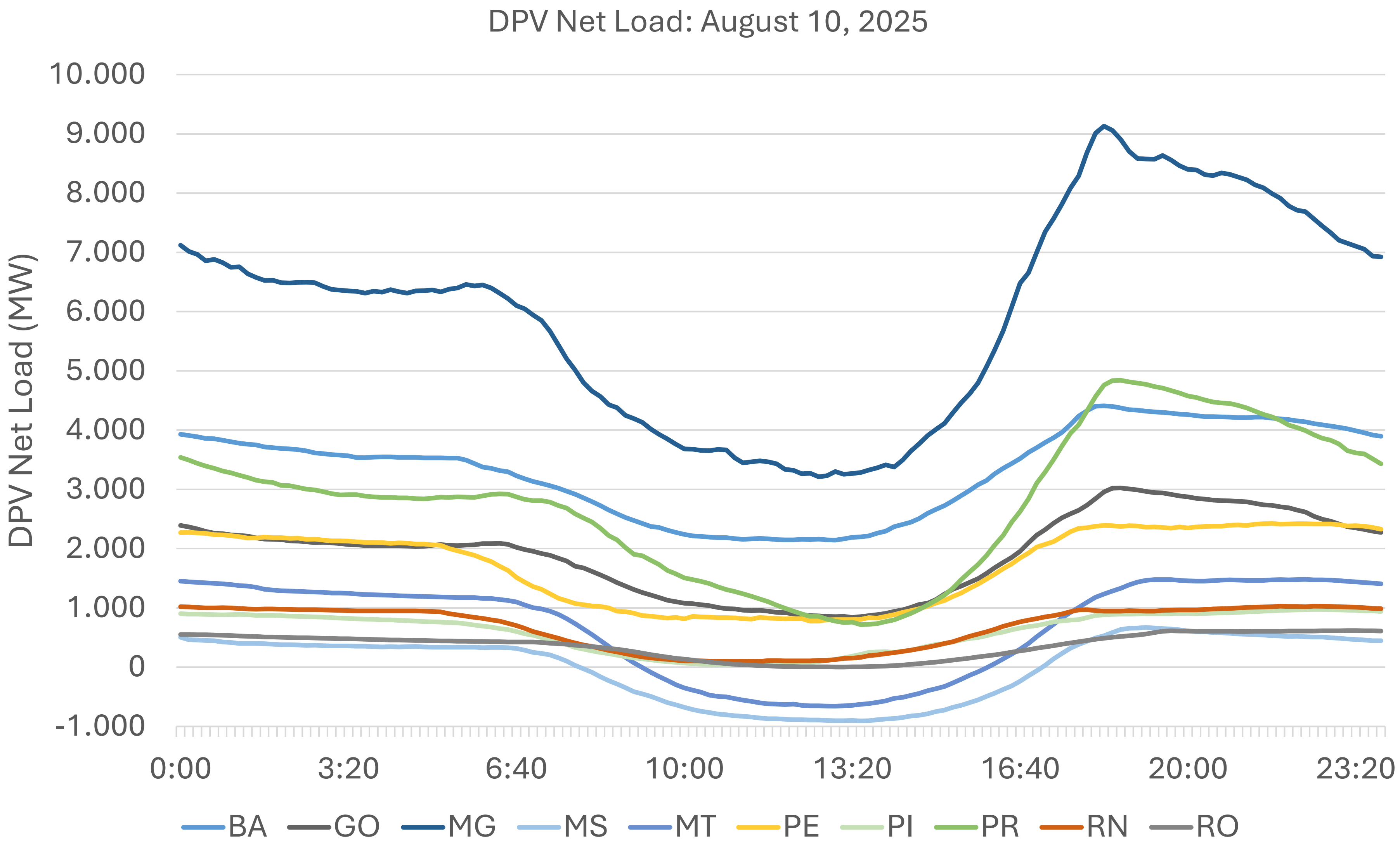


Record of the Minimum Net Load



The challenge is operating a system where nearly half of the generation may come from distributed resources

DPV Net Load



Negative DPV net load in the states of Mato Grosso (MT) and Mato Grosso do Sul (MS)

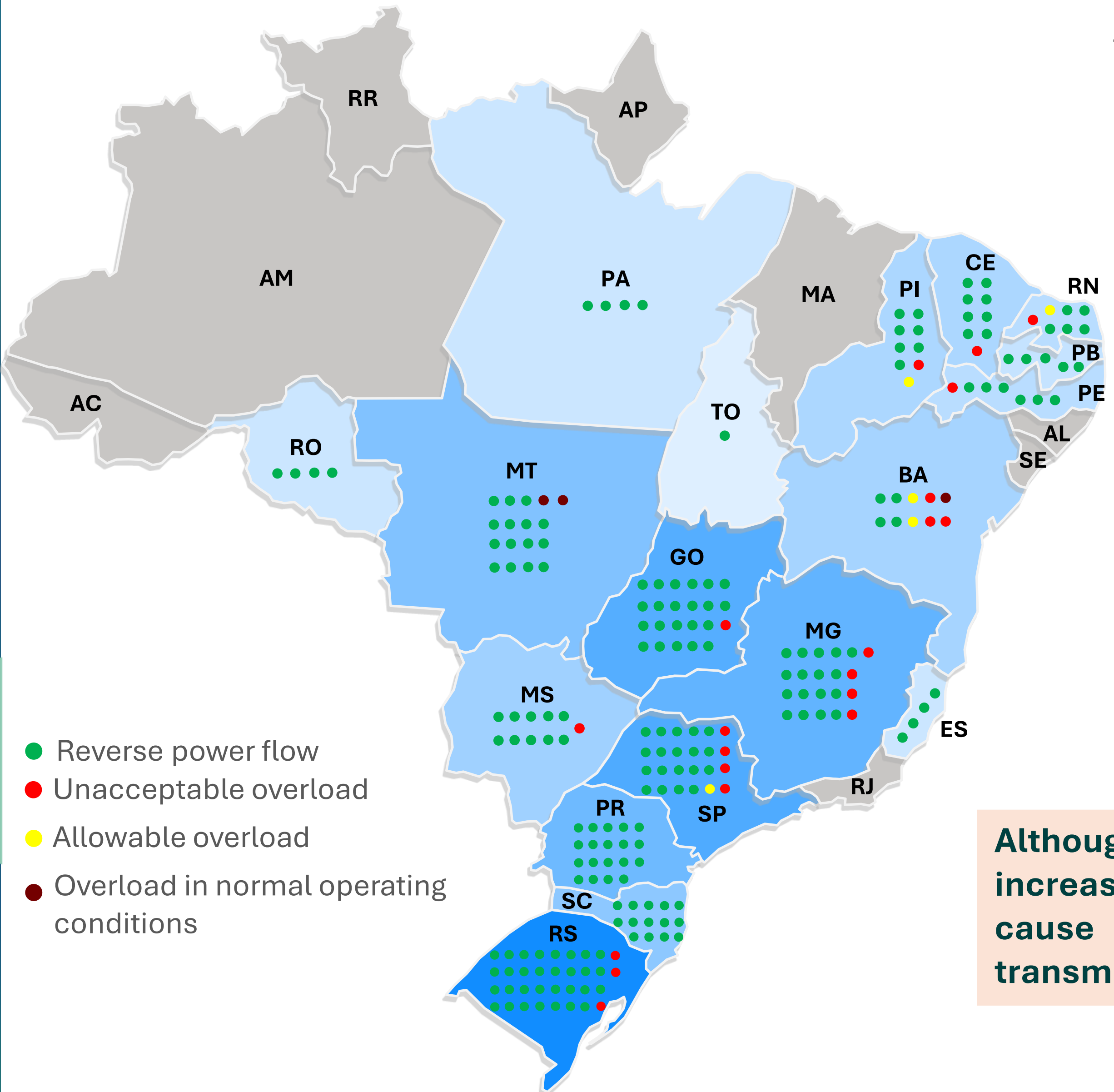
Minimum negative DPV net load:
MT (657 MW) and MS (906 MW)

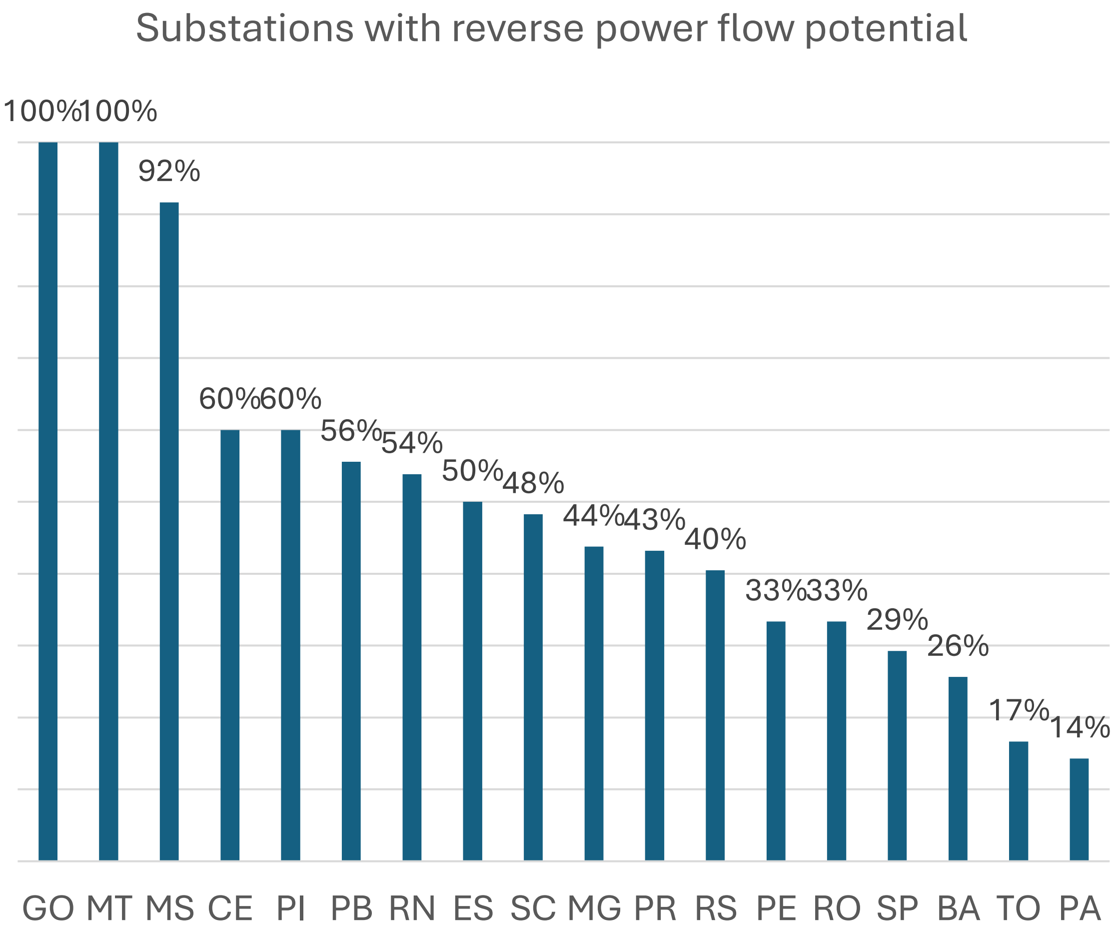
Daily range of DPV net load in Minas Gerais (MG): 5,900 MW

In some states, DPV generation already exceeds local demand during daytime hours

Operador Nacional do Sistema Elétrico

Reverse Power Flow at the Transmission–Distribution Interface



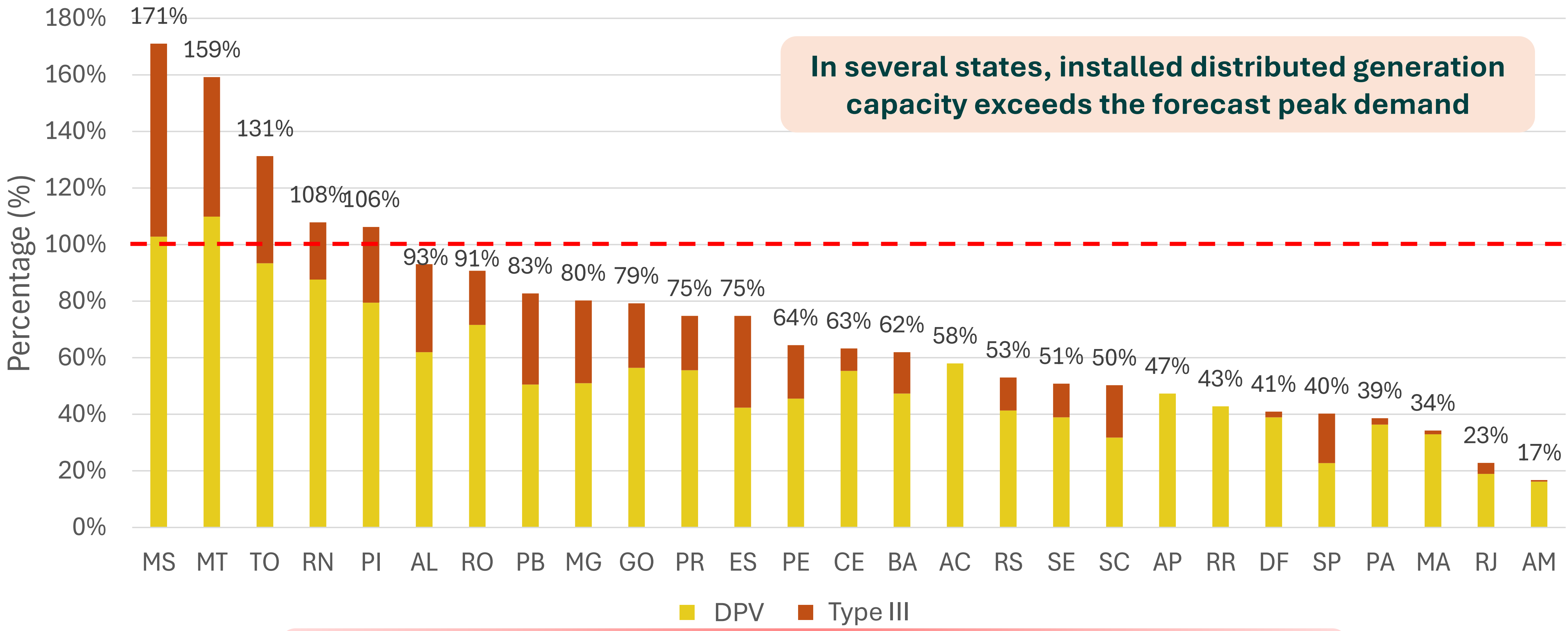


Although reverse power flow is not a system-wide problem, it may increase the need for curtailment of centralized generation and cause overloads in the bulk transmission system and at the transmission–distribution interface.

Operador Nacional do Sistema Elétrico

Distributed Generation Contribution to Peak Demand

$$Percentage\ (\%) = \frac{DG\ Installed\ Capacity\ (DPV + Type\ III)}{\text{Forecast Peak Demand for 2026}}$$



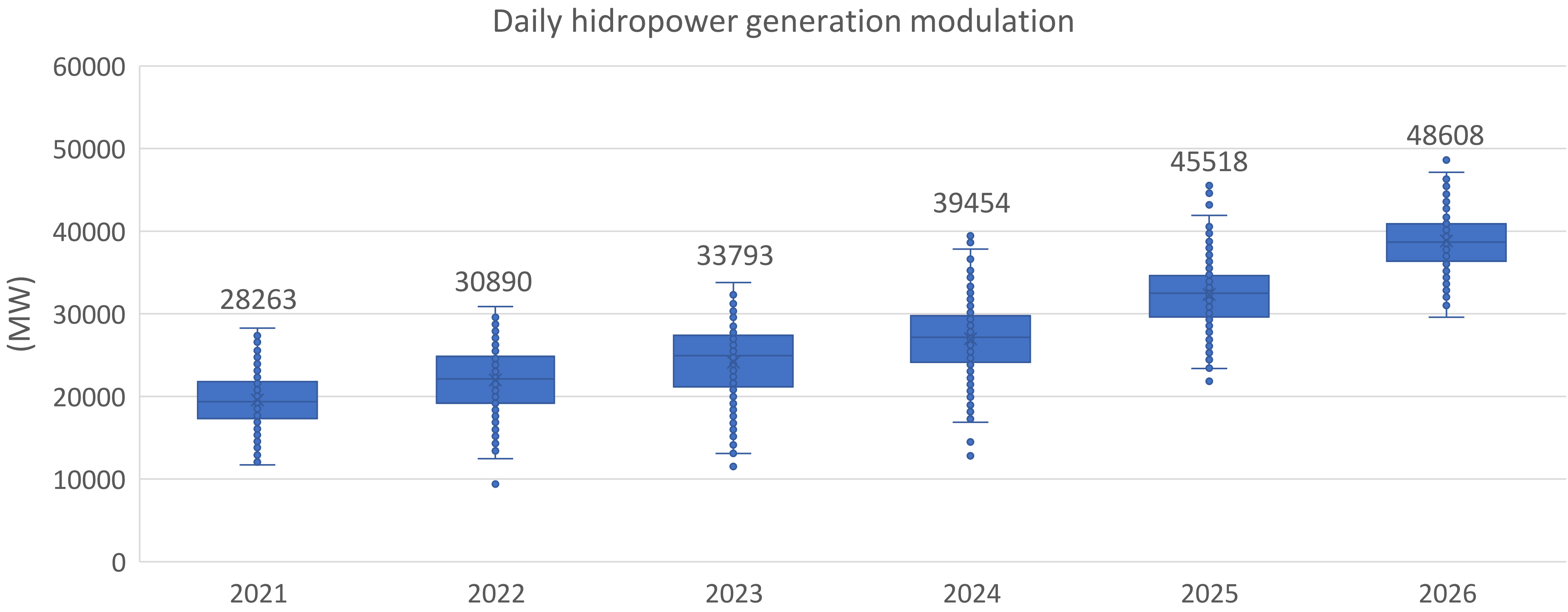
The DG is no longer just a consumer resource. It becomes an important factor in transmission planning and real-time system operation.

ONS Operador Nacional do Sistema Elétrico

Daily Hydropower Generation Modulation

The rapid growth of wind, solar and DPV generation is increasing system variability and the **need for operational flexibility**.

Hydro power plants are the primary source of operational flexibility in the Brazilian power system, rapidly adjusting its output to balance generation and demand in real time.



As variable generation has increased, the daily modulation required from hydropower has also increased

Impacts of Distributed Generation on System Operation

Shifting power generation from large-scale centralized power plants to small-scale and distributed resources

- Increasing need for operational flexibility
- TSOs must manage more real-time variability in demand with fewer dispatchable tools
- Bidirectional power flow across the transmission–distribution interface
- Management of transmission constraints in the bulk power system
- Evolving role of DSOs and closer TSO–DSO coordination

Characteristics of variable generation

Connected to distribution system via inverters

Not controllable by ONS

Lack of support for the dynamic performance of the electrical system

The main challenge is no longer transmitting large blocks of electricity. Today, it's about coordinating millions of distributed energy resources while maintaining the secure operation of an increasingly renewable and variable power system.

ONS Operador Nacional do Sistema Elétrico

ONS Actions to Address DERs Impacts

ONS/DSO Interface Project

Developing a regulatory framework for the coordinated management of DERs and Type III generation in collaboration with DSOs

Distribution Network Generation Surplus Management Plan

Establishing procedures for the emergency reduction of Type III power plants under critical generation surplus conditions in the power system

Load and DPV Modelling

Load and DPV modelling for stability studies (CLM + DER_A adapted to the Brazilian context)

Revision of PRODIST Module 3

Updating the technical requirements in the Distribution Grid Code (PRODIST) for DERs interconnection

Regional Generation Reduction Scheme

Over-frequency protection settings for the automatic disconnection of Type III power plants and DERs

Distribution Network Generation Surplus Management Plan

A standardized and transparent emergency procedure to preserve system security during periods of very low net load.

- ✓ Exceptional, preventive and emergency measure;
- ✓ Activated when available centralized generation redispatch (reduction) options for frequency control are close to being exhausted;
- ✓ Reduction of distribution-connected Type III power plants.

Weekly Horizon (D-2 ... D-7)	D-1	Real time operation	Post-Operational Analysis
Forecasting the exhaustion of centralized generation redispatch capability during minimum net load periods.	Confirmation of the need for generation reduction in the day-ahead schedule.	Execution of reduction for distribution-connected Type III power plants	Post-operational assessment of plan effectiveness.
Notification to DSOs.	Communication of the required reduction level and period to DSOs.		

Revision of PRODIST Module 3

PRODIST Module 3 defines the technical requirements for DER interconnection to the distribution network in Brazil

Modernizing the regulatory framework for distribution network interconnections to address the growing operational complexity of the Brazilian power system

Enabling the active participation of DERs in power system operation, allowing them to provide essential services for the security of the Brazilian power system

- Voltage and frequency ride-through requirements
- Integrating diverse energy technologies, including DERs and energy storage
- Modernizing interoperability and communications requirements
- Revising power quality requirements
- Enabling DERs to actively support power system operation
- Enhancing DERs response capabilities during system disturbances

Regional Generation Reduction Scheme

- Coordinated proposal for over-frequency protection settings for the automatic disconnection of DER;
- Emergency and temporary operational measure until structural DER management solutions become available;
- Activation only under sustained over-frequency emergency conditions.

Current and future operational scenarios

- Growing contribution of resources not controllable by ONS (DPV and type III power plants);
- Reduction of net load;
- Potential exhaustion of centralized generation redispatch capability;
- Under more severe operating conditions, this scenario may lead to sustained over-frequency.

Regional generation reduction scheme

- A short-term measure for sustained over-frequency control;
- Automatic activation through the implementation of time-delayed over-frequency protection settings;
- Restoration of the “generation-load” balance.

Considerations

- **Distributed generation**, predominantly composed of small-scale photovoltaic systems, is already the **second-largest generation source** in Brazil.
- **Lower minimum net load** increases the need for **operational flexibility** and **voltage control resources**, particularly to manage the demand variations during the transition from daytime to evening.
- **Reverse power flow** at the transmission–distribution interface may lead to **transmission equipment overloads** and **increased centralized generation curtailment** to preserve system reliability.
- **Modernizing technical requirements for DER connection** to distribution networks.
- Enhancing the **controllability of DER by DSOs**, in close coordination with the **TSO**, is essential.

Future Operation in Brazilian Interconnected Power System

Impacts of Electricity-Intensive Loads

Emerging large loads are **predominantly power-electronics-based** and interact with the grid in different and unknown ways, creating **new operational and planning challenges**

NETWORK IMPACTS

- Large load blocks occupy or exceed the available transmission capacity;
- The existing network may experience overloads or voltage violations;
- Need for network reinforcements and capacity upgrades.

GRID CODE & PROTECTION REQUIREMENTS

- LVRT/HVRT capability;
- Frequency ride-through;
- Rampe-rate limits;
- Reactive power support;
- Dynamic models for EMT and RMS studies.

DYNAMIC BEHAVIOR

- Rapid MW ramps and short-term variability;
- Load oscillations and interactions with IBRs;
- Fault-induced load reduction or disconnection.

SYSTEM OPERATION

- Real-time monitoring;
- Accurate forecasting of large load behavior;
- Coordination between load owners and system operators;
- Increase in peak demand of the interconnected system.

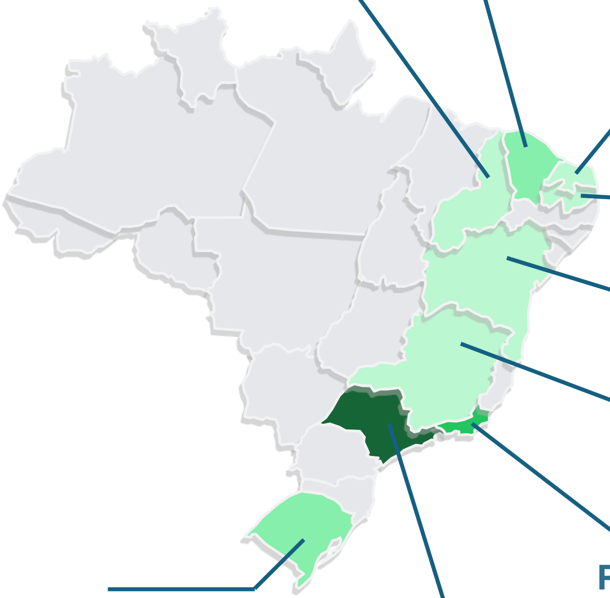
TRANSMISSION EXPANSION PLANNING

- Long-term demand visibility and commitments;
- Consideration of load growth timing and location;
- Flexibility needs.

These loads are becoming active participants in power system dynamics. Their integration requires new technical requirements, dynamic models and strong operational coordination

Large Electric Loads

Information on data center projects that submitted grid connection requests to the ONS:



Total: 18,659 MW

CUST Executed:	Not feasible:	Under evaluation or awaiting CUST execution:
2,278 MW	3,277 MW	13,105 MW

- So far, a total of **134 projects** have been identified, including **55 in the state of São Paulo**.
- Approximately **6.9 GW** are concentrated in the **state of São Paulo** alone.
- In the Northeast region, Data Center projects **"compete"** with **H2 projects** for grid access.

In addition to the data center projects, there are **hydrogen projects** with CUST executed, totalling **2,160 MW** of demand. All of these projects will be connected in the state of **Ceará**.

ONS Operador Nacional do Sistema Elétrico

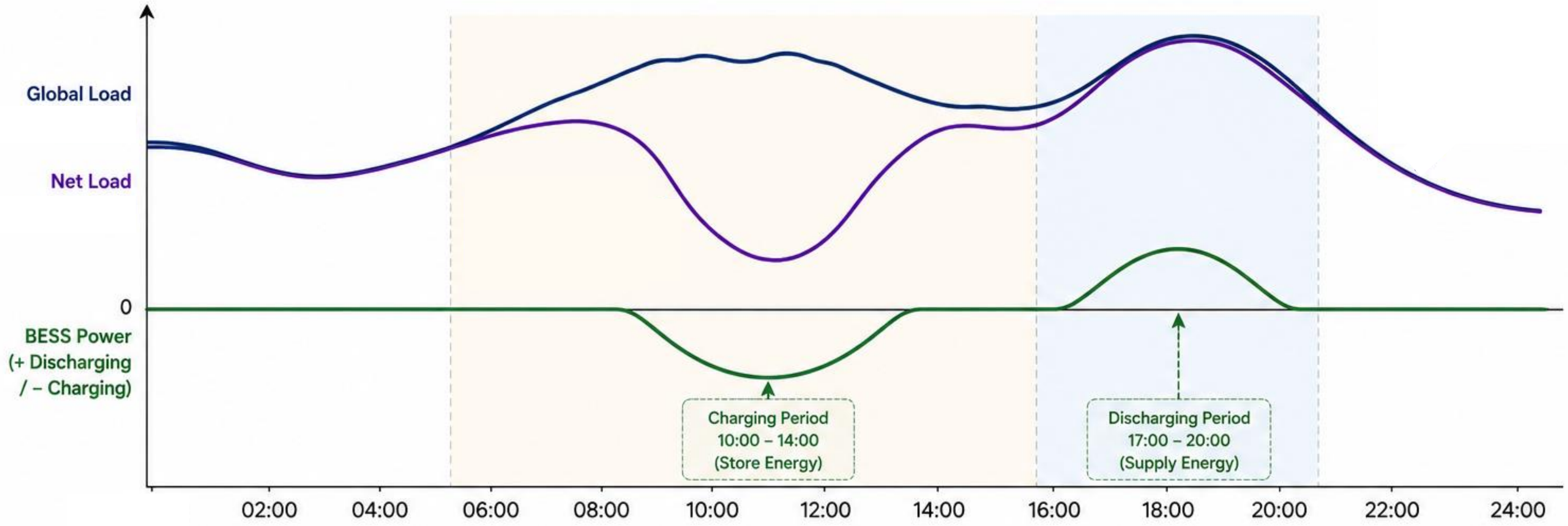
Information up to July 2026

Battery Energy Storage Systems (BESS)

- The **first auction for Battery Energy Storage System (BESS)** integration into the Brazilian Interconnected Power System is scheduled for **December 2026**;

- **BESS dispatch will be coordinated by ONS** to meet system operational requirements;

- Among other benefits, BESS deployment can help **reduce renewable generation curtailment during the day (charging period)** and **enhance the reliability of meeting peak demand (discharging period)** in the late afternoon/night.



BESS can become an important source of operational flexibility for the BIPS

PNAST – National Policy for Access to the Transmission System

- Over the last few years, **Brazil has experienced a rapid expansion of renewable generation**, especially wind and solar power, together with the growth of the **new large consumers** more recently. This rapid expansion led to a **significant increase in transmission access requests;**

- As a result, the previous **first-come, first-served** approach was no longer able to provide an efficient process for allocating transmission capacity or supporting long-term transmission planning;

- Brazil has introduced periodic **Transmission Access Windows** under the PNAST. During each access window, transmission access requests are evaluated jointly to **optimize the allocation of available network capacity** and **improve transparency and efficiency** in the connection process.

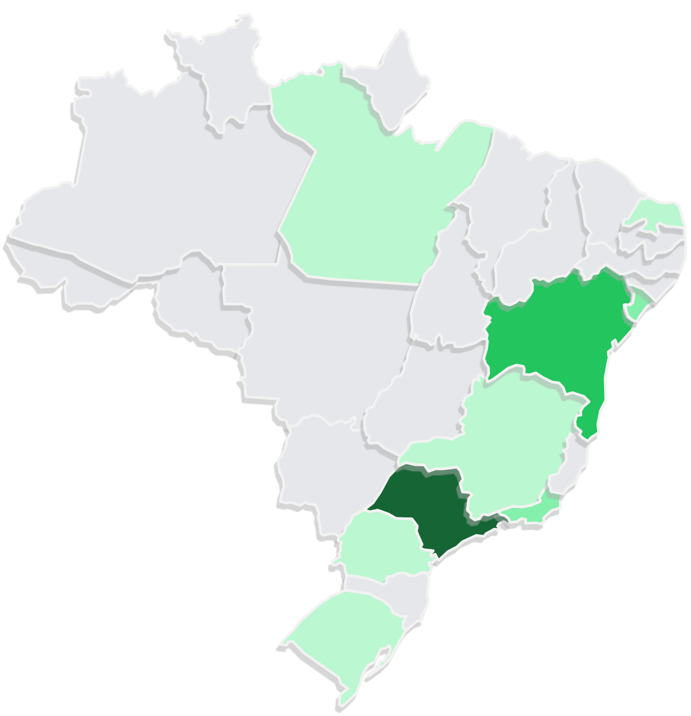
Aspect	Previous Model	PNAST
Application Process	Applications were submitted and evaluated individually on a **first-come, first-served** basis.	Applications are submitted within predefined **Transmission Access Windows** and evaluated simultaneously.
Available Capacity	Evaluated **individually** for each access request.	Available transmission capacity is published for **substations, substations groups, and transmission areas**.
Competition	**Time of application determined priority** for capacity allocation.	If demand exceeds the available capacity, a **competitive allocation process** is applied.

PNAST – National Policy for Access to the Transmission System

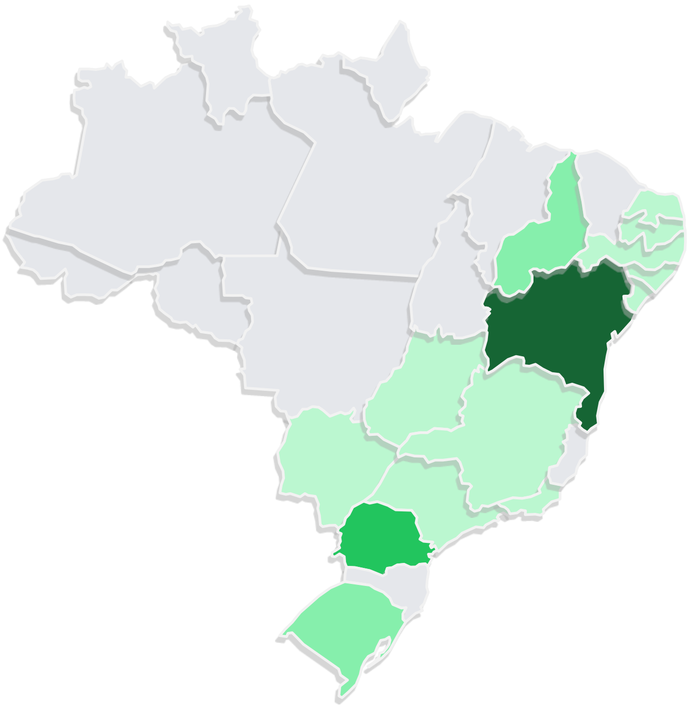
- The project admission phase for the first Access Window closed on June 30. Of the 367 admitted projects, 288 are generation facilities and 79 are consumer units. The total admitted capacity amounts to **20.31 GW**.

- ONS is currently assessing the available transmission capacity to accommodate the projects submitted during the first Access Season. The assessment results will be published on August 31, 2026.

Load
5,749.3 MW



Generation
14,568.5 MW

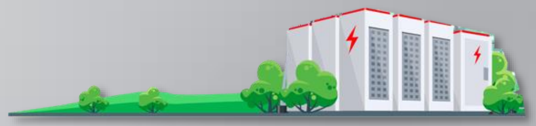


The first Access Window confirms the strong demand for transmission access from both new generation and loads

Operation in the future

Growing increase in Distributed Photovoltaic (DPV). The installed capacity by July 2026 was 50.9 GW and by 2031 the forecast is 73 GW;

Increasing complexity in operation due to the growing penetration of intermittent renewable sources;



New technologies arriving on the electricity market, mainly storage, which allows greater integration of renewable sources and offers flexibility;

Massive incorporation of technology to deal with climate change.

ONS Operador Nacional do Sistema Elétrico

Thank you

Operador Nacional do Sistema Elétrico – ONS

Júlio César Cândido Vieira
(julio.vieira@ons.org.br)