Brazil - 2021

# Strategic Market Report

# Brazilian Energy Storage Market

## Applications, Technologies & Financial Analyses

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# Chapter 1

## How storage is changing the electrical energy sector around the world

# THE ROLE OF STORAGE IN THE TRANSFORMATION OF THE ENERGY SECTOR

## Generation

Large-scale storage systems provide important services to energy generators, such as:

- Facilitation of energy dispatch from large renewable energy plants (solar, wind), absorbing peaks in energy generation and transferring them to moments of peak loads;
- When used in conjunction, energy storage and PV solar systems can substitute diesel generators in off-grid energy systems.

## Transmission + Distribution

In the areas of energy transmission and distribution storage systems can offer:

- Improved grid efficiency: instead of building new transmission lines or substations to meet temporary peaks in demand or supply grid operators can use storage in strategic locations throughout the grid;
- Higher quality / more reliable supply of electrical energy: storage allows grid operators to absorb fluctuations in voltage or frequency, thereby contributing to a reduction in power interruptions and blackouts (ancillary services).

## Consumption

For the individual consumer, energy storage systems can result in a range of important advantages, such as:

- Manage energy consumption and demand charges;
- Serve as an energy backup;
- Reinforce the advantages of distributed generation/solar energy;
- Provide ancillary services (remunerated) to the grid;

Energy storage systems allow the energy consumer to become a 'prosumer', thus providing an important increase in the level of energy autonomy and independence.

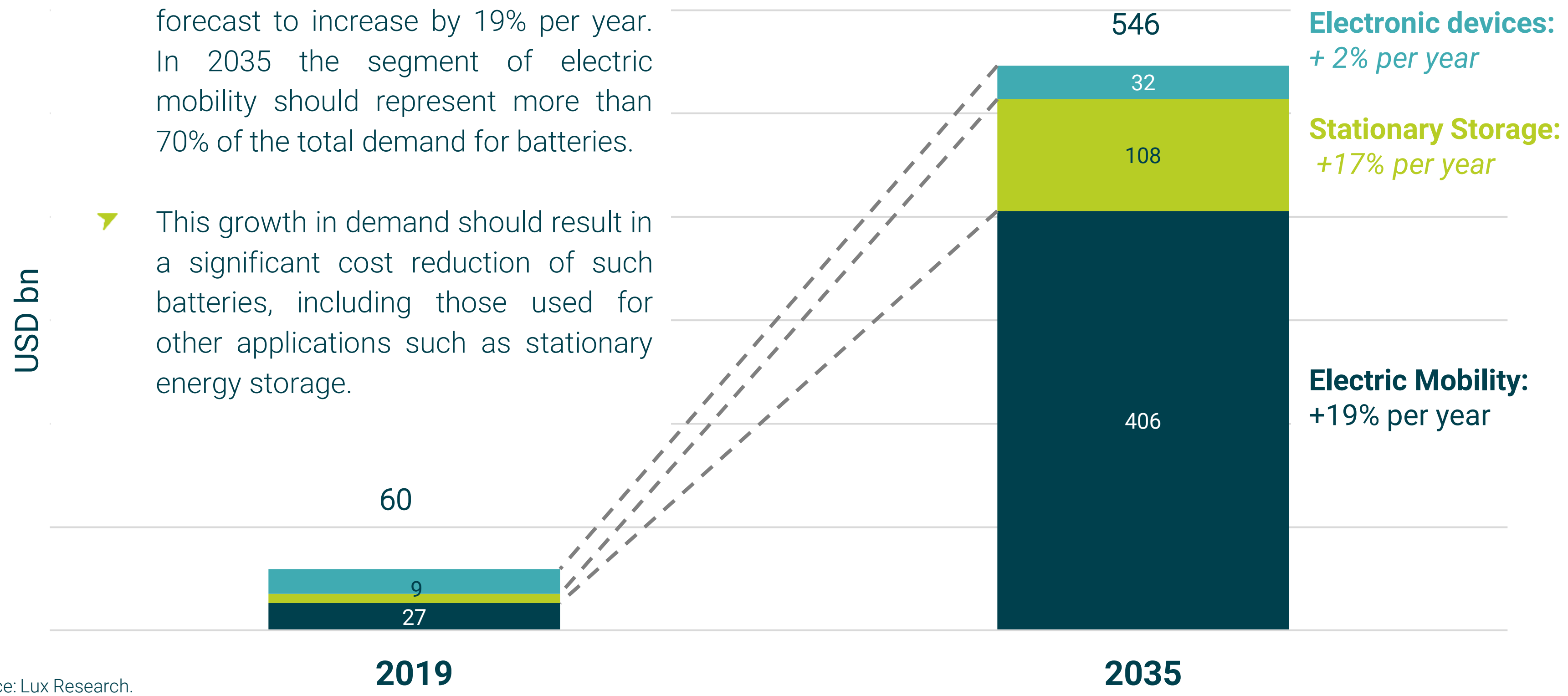
Storage Systems **'in front of the meter'**

Systems **'behind the meter'**

# GLOBAL REVENUES FROM ENERGY STORAGE

- Between 2020 and 2035 the demand for batteries for electric mobility is forecast to increase by 19% per year. In 2035 the segment of electric mobility should represent more than 70% of the total demand for batteries.

- This growth in demand should result in a significant cost reduction of such batteries, including those used for other applications such as stationary energy storage.




Source: Lux Research.

# Chapter 2

## The silent technological revolution of batteries

# COMPARISON OF MAIN BATTERY TECHNOLOGIES

| | Lead-acid | Lithium-ion | Flow batteries |
|---|---|---|---|
| Chemical Composition | Pb + H2SO4 | LFP*, NMC*, NCA*, ... | Vanadium-Redox, Iron-Chromium, Zinc-Bromide |
| Discharge time | Flexible, can be optimized to reach up to 20 hours | Up to 4 hours | 4 – 10 hours |
| Useful life (cycles) | 200 - 800 | 2,000 – 8,000 | 10,000 – 15,000 |
| Total efficiency | 60%-70% | 85%-98% | 60%-85% |
| Energy density | Low | High | Medium |
| Price (USD) | Up to USD 100/kWh | Up to USD 200/kWh | USD 200 – 600/kWh |
| Safety | Medium | Low - Medium | Not flammable, but leaks are possible |
| Toxicity | High | Medium | Depends, e.g. Bromium is highly toxic |

Positive characteristic

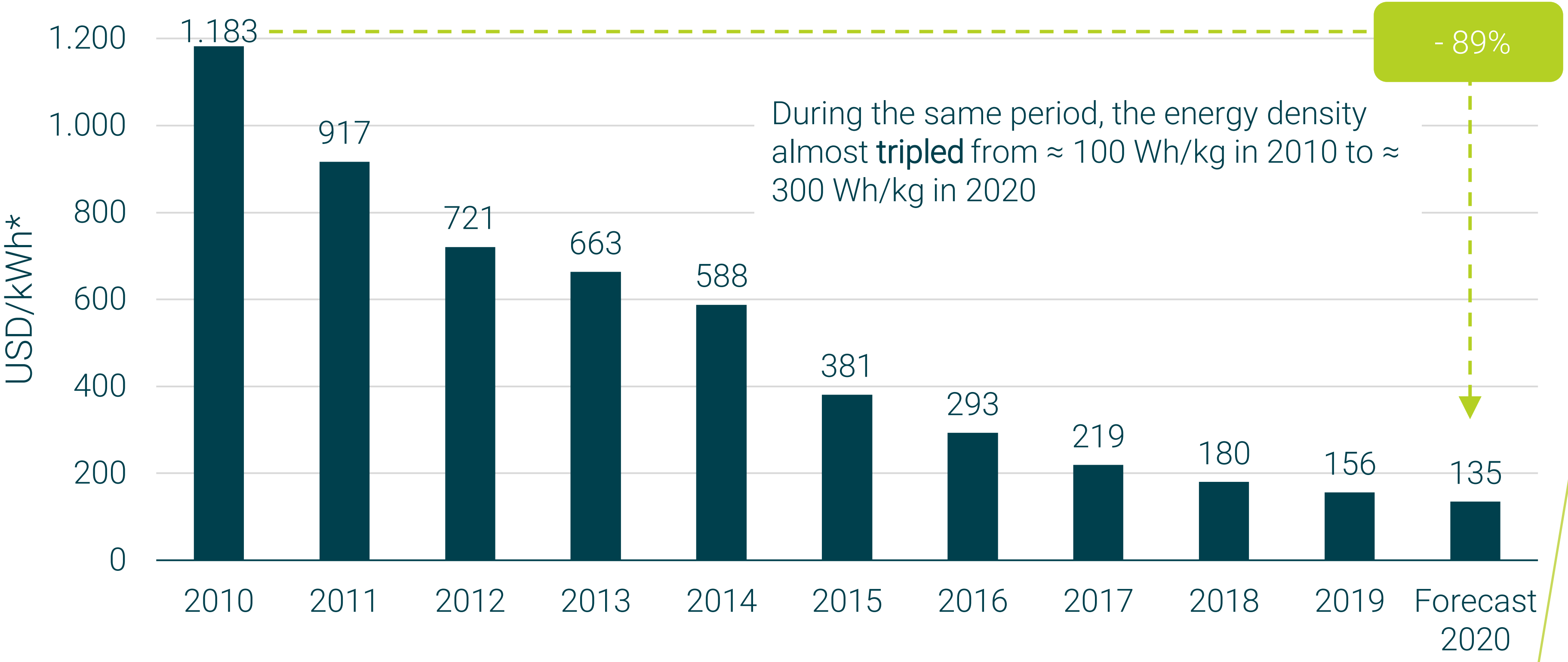
Negative characteristic

Other technologies:

- Zinc-air;
- Sodium-Sulphur;
- AHI (aqueous hybrid ion);
- Sodium-Ion.

Source: IFC, authors' analyses.

# PRICE OF LITHIUM* BATTERIES HAS FALLEN BY 89% SINCE 2010



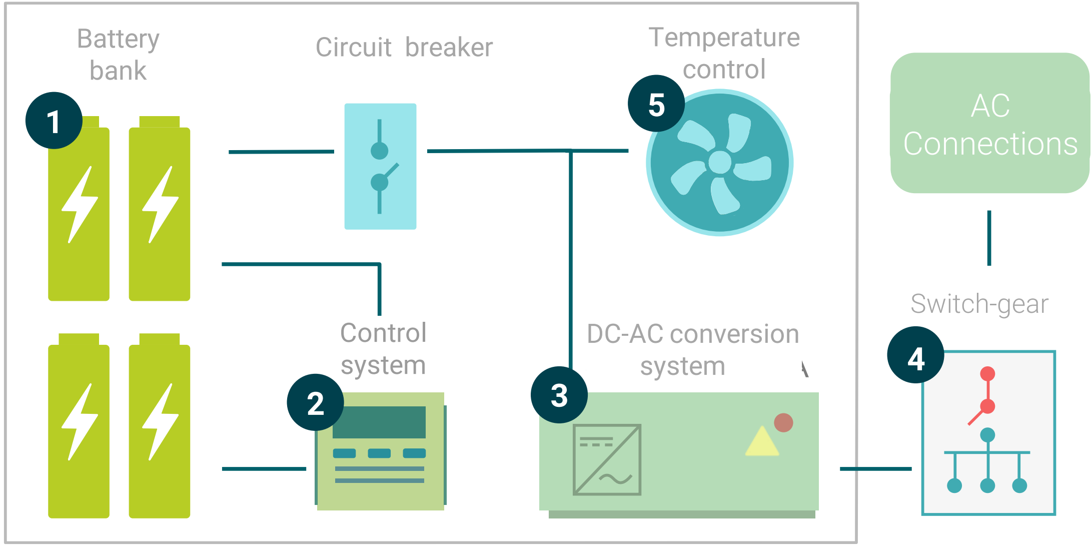

Source: BNEF, Cleantechnica.

* Battery pack composed of battery cells, BMS (battery management system), electrical contacts and housing

# FUTURE SCENARIOS FOR BATTERY TECHNOLOGIES

| | | |
|---|---|---|
| 1 | The battery market will be dominated by **one** or **two anchor technologies**. Other technologies will only be commercialized for niche applications. | **Plausible scenario.** Electric mobility requires batteries with elevated energy densities. Among commercially available battery technologies only **lithium batteries** have a chance of reaching satisfactory levels of energy density. Economies of scale and learning-curve effects will also facilitate the adoption of lithium batteries for stationary applications;<br>**Lead-acid batteries** could remain relevant for 'classical' applications such as simple energy backup systems or as starter batteries in vehicles; |
| 2 | **Various battery technologies will coexist** in the marketplace:<br>Lithium for electric mobility and electronic devices;<br>Flow batteries, zinc-air batteries, and lead-acid batteries for stationary applications; | **Possible, but less likely**. The industrialization of new technologies requires very large investments. The fragmentation of demand between various technologies will reduce the economies of scale that could be obtained in the future; |
| 3 | Discovery and rapid adoption of one or more new '*killer technologies*'. | **Possible, but highly unlikely** in the short to medium term. |

# MAIN COMPONENTS OF A BATTERY-BASED ENERGY STORAGE SYSTEM




**5 Temperature Control**

- Temperature and humidity sensors;
- System for air conditioning or heating;
- Fire suppression system.

**4 Switchgear**

Controls the connection between the energy storage system, customer loads, and the grid.

**3 Conversion System**

- Converts the energy stored in the battery from Direct Current (DC) to Alternating Current (AC) and vice versa.

**1 Battery bank**

Blocks of individual batteries arranged in 'racks'. Can be lithium batteries or other technologies, depending on the type of application.

**2 Control System**

- Management software (EMS: *energy management system*), taking care of managing and dispatching stored energy;
- Technical supervision ensuring the correct interaction between the various components of the system (batteries, inverters, energy meters);
- Communications interface allowing remote supervision and operation.

# COST STRUCTURE – COMMERCIAL SYSTEM

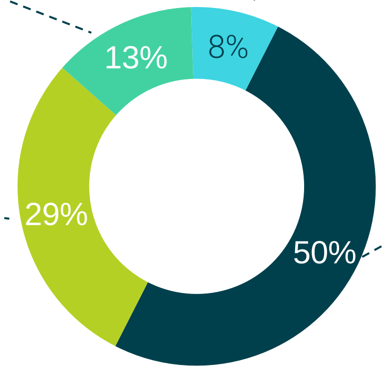
## Batteries represent almost 50% of total system cost

**Other components**

- Engineering;
- Installation.

**Inverter / converter**

- AC/DC converter (for charging and discharging the batteries);
- Software for system management (EMS – *energy management system*).




**Other costs**

- Electrical protection equipment;
- Transfer boxes;
- Container or storage box;
- Other components.

**Battery bank**

- Battery cells;
- Racks ('technical drawers' grouping the cells in battery banks of 2-15 kWh);
- BMS (*battery management system*).

!

In Brazil, the tax rates applied to batteries and converters can reach up to 80%.

Source: analyses by author.

# Chapter 3

## How energy storage is beginning to change the electrical energy sector in Brazil

# APPLICATIONS IN THE BRAZILIAN ELECTRICITY SECTOR

| | |
|---|---|
| **Off-Grid** | Batteries have been used in smaller off-grid systems for many years. Using Lead-acid batteries, this is the oldest application of energy storage in Brazil. Programs for universalization of access to electrical energy, such as "Mais Luz" in the Amazon region, will continue to drive this market.<br><br>Hybrid Applications – Solar + Diesel + Batteries – have gained competitiveness, reducing costs and CO2 emissions. Isolated communities and rural energy consumers already use these solutions, for example for crop irrigation.<br><br>In the context of the ANEEL* energy storage R&D program (ANEEL program n˚ 21/2016) a micro-grid project with battery storage was created on the island of Fernando de Noronha, which could serve as a reference for other off-grid systems in the rest of the country. |
| **Behind the Meter** | 'On-grid' energy storage projects behind the meter are a recent phenomenon in Brazil. In addition to R&D projects, the first generation of commercial projects have already been implemented. |
| **In Front of the Meter** | In-front-of-the-meter projects are not yet commercially viable, due to a lack of specific regulation. However, several R&D projects have been completed in the context of ANEEL's energy storage R&D program and serve as references for the regulatory adjustments that need to be made. |

* ANEEL (Agência Nacional de Energia Elétrica): federal regulatory agency for the electricity sector.

# BEHIND-THE-METER ENERGY STORAGE

## Behind-the-meter applications in Brazil

| Application | Medium and high voltage users (Group A) | Low voltage users (Group B) | | |
|---|---|---|---|---|
| | | Conventional Tariff | White Tariff | Binomial Tariff |
| **Backup** | ● | ● | ● | ● |
| **Reduction of Peak Demand** | ● | ✗ | ✗ | ● |
| **Management of Consumption during Peak Hours** | ● | ✗ | ● | ◍ |
| **Distributed Generation without Grid Injection** | ● | ● | ● | ● |

◍ Only if the volumetric component is measured per time slot

- Not all types of storage applications can be used by all types of energy consumers. It should be emphasized, however, that a system can provide more than one service at the same time, thus increasing its financial return. The exhibit on the left shows some of the storage applications that can be used to the benefit of customers, grouped by customer type and energy tariff structure.

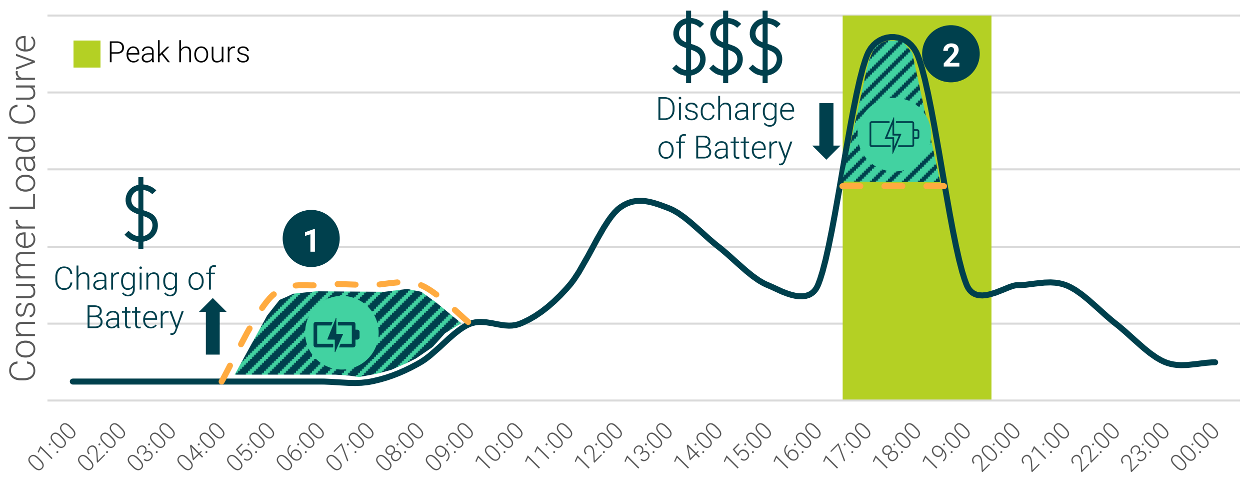
# REDUCTION OF ENERGY CONSUMPTION DURING PEAK HOURS

## Behind-the-meter applications in Brazil

- The reduction of energy consumption during peak hours, when electric utilities charge highest rates, is among **the most attractive applications** of energy storage. Some electric utilities charge **a very large price difference between peak and off-peak** rates. The bigger this difference is, the bigger the savings that can be obtained. Consumers with limited capacity to reduce consumption during peak hours can take advantage of an energy storage system to store energy during the low-cost off-peak hours and then discharge the batteries (lowering the use of grid energy) during the peak hours when electricity is more expensive.

1. During off-peak hours the batteries are being charged.
2. During peak demand hours, from **5 pm to 8 pm,** the batteries are discharged, thus reducing energy consumption from the grid.

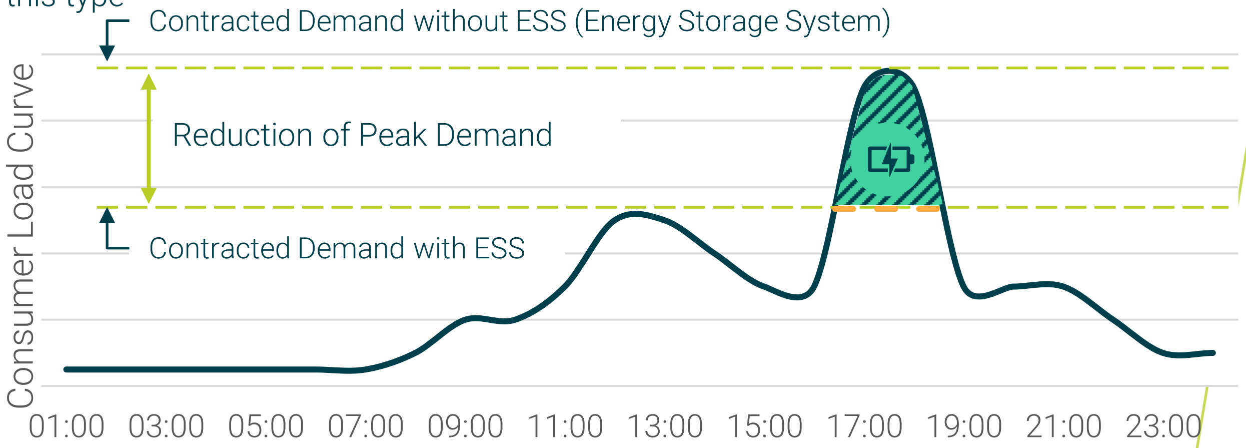
- The continuous blue line represents the load curve without storage, while the dotted orange lines show the adjusted curve with storage.



# REDUCTION OF DEMAND CHARGES

## Behind-the-meter applications in Brazil

- Using energy storage systems to reduce demand charges (i.e., the amount of power contracted with the electric utility) can result in significant savings for users whose consumption patterns are marked by short intervals with significant demand peaks. Such demand peaks may be caused by a variety of industrial equipment, such as motors, compressors, and similar devices. In such cases, energy storage systems are configured to absorb those demand peaks, which contributes to **reducing energy costs**.
- This application is less relevant for users with extended demand peaks, or with an average demand that comes close to the amount contracted with the electric utility (i.e., users with high load factors). Consumers that are **frequently fined for surpassing their contracted demand** could also benefit. The higher the cost of contracted demand, the more attractive an energy storage system becomes for this type of application.
- The green area corresponds to the energy supplied by the batteries to reduce peak demand. The batteries can be then charged during moments with lower consumption and reduced demand. The dotted orange line shows the demand curve during the period of peak consumption while using the storage system.



# MARKET FOR ENERGY STORAGE IN FRONT OF THE METER

## Hybrid Power Plants
(Generation + Storage)

- The lack of grid-connection points is one of the main hurdles for implementing new large-scale PV solar and wind projects.
- Energy storage allows to modulate peak power and can thus facilitate the implementation of new projects.

- **More effective economic signals could accelerate the development of such hybrid plants.**

## Transmission & Distribution

- Studies analyzing the Brazilian energy distribution sector indicate that storage systems could contribute to optimizing investments in substations and other distribution assets.

- **Currently energy providers have no incentive to adopt storage as an optimization measure.**
- **Specific regulatory action is required to promote this type of innovation.**

## Ancillary Services

- Compared to other countries, Brazil suffers from frequent power outages and significant grid oscillations. Energy storage systems, installed at critical points of the energy grid could contribute to solving these problems.
- However, current regulations do not provide adequate incentives for using storage systems for ancillary services.

- **Also requires specific regulatory action.**

# Chapter 4

## Achieving economic viability

# IN-DEPTH ANALYSIS

## BEHIND-THE-METER STORAGE FOR MEDIUM VOLTAGE CONSUMERS

| Medium Voltage | | |
|---|---|---|
| Captive Consumer* | We will evaluate the economic viability of energy storage systems in the contexts of reducing consumption during peak hours and reducing contracted demand. | We will present the regional differences in economic viability. |
| 'Free' Market Consumer ** | For large-scale consumers on the so-called 'free energy market' we will evaluate the possibility of generating savings concerning the TUSD*** charge at Peak *vs.* Off-Peak Hours. | |

* Consumers with contracted demand up to 500 kW must purchase electric energy from their regional electric utility;

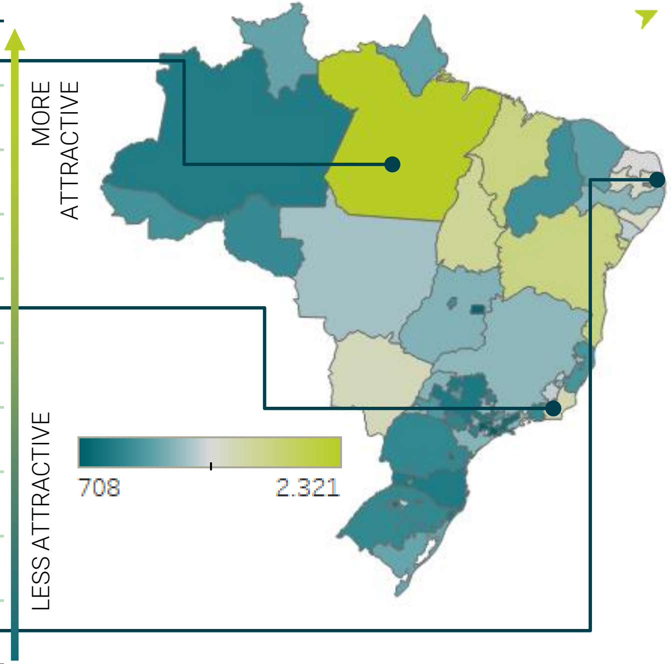
** Consumers with more than 500 kW of contracted demand can buy energy from third parties, but still need to contract demand with their local utility and pay transmission and distribution (T&D) charges to that utility;

*** TUSD: transmission and distribution charges (T&D).

# REDUCTION OF CONSUMPTION DURING PEAK HOURS

## Attractivity map for medium voltage users

| Electric utility | State | Δ P-OP* (BRL/MWh) |
|---|---|---|
| Equatorial PA | PA | 2.419 |
| Cemar | MA | 2.066 |
| Coelba | BA | 1.889 |
| Sulgipe | SE | 1.846 |
| ENF | RJ | 1.825 |
| ETO | TO | 1.797 |
| EPB | PB | 1.761 |
| Enel RJ | RJ | 1.688 |
| EMS | MS | 1.646 |
| CEAL | AL | 1.618 |




The exhibit on the left shows the top ten electric utilities in terms of savings potential during peak hours. The bigger the difference between peak and off-peak rates, the more attractive energy storage becomes. A few very small local utilities operate with even larger differences, but due to their limited size, they have been excluded from this analysis. The state of Pará offers the highest attractiveness for this type of energy storage application.

* Difference between peak and off-peak electricity rates for medium-voltage consumers with A4-Verde (Green) tariff. Database: 2020. Without taxes.

# CASE STUDY – COMMERCIAL MEDIUM-VOLTAGE CLIENT
## Simulation assumptions

- To guide readers about the **attractiveness of an investment** in energy storage systems we carried out several simulations, and in the following slides, we present the **financial results**, based on our models and assumptions.

- The simulated customer profile is that of a large-scale captive commercial energy consumer who will use storage both to reduce energy consumption during peak hours and demand charges.

- The results can change depending on the **specific project**, the **profile of energy use**, the **operating conditions of the storage system,** among other factors. This analysis intends to provide **viability guidelines** for an energy storage projects.

| | |
|---|---|
| **Type of consumer** | Commercial |
| **System size** | 500 kWh /500 kW |
| **Energy market** | Captive market |
| **Tariff group** | A4 Green |

# CASE STUDY – TECHNICAL ASSUMPTIONS

## Simulation assumptions

- The table shows the main technical assumptions used for our modeling of financial attractiveness. The values were obtained through literature research and a collection of data from equipment suppliers.
- The values can change depending on the equipment provider and project type **should not be treated as a reference for all storage projects**.

| | |
|---|---|
| Battery technology | Lithium ion |
| Depth of discharge * | 92.5% |
| Lifespan | 15 years |
| Degradation<br>(1st year/later years) | 3.0% p.a. / 0.5% p.a. |
| Roundtrip efficiency * | 87.5% |
| Nº of cycles | 5 x per week |

* Depth of discharge: percentage of nominal storage capacity of a battery that is actually being used. Roundtrip efficiency: 'all-in' electric efficiency during charging and discharging of the energy storage

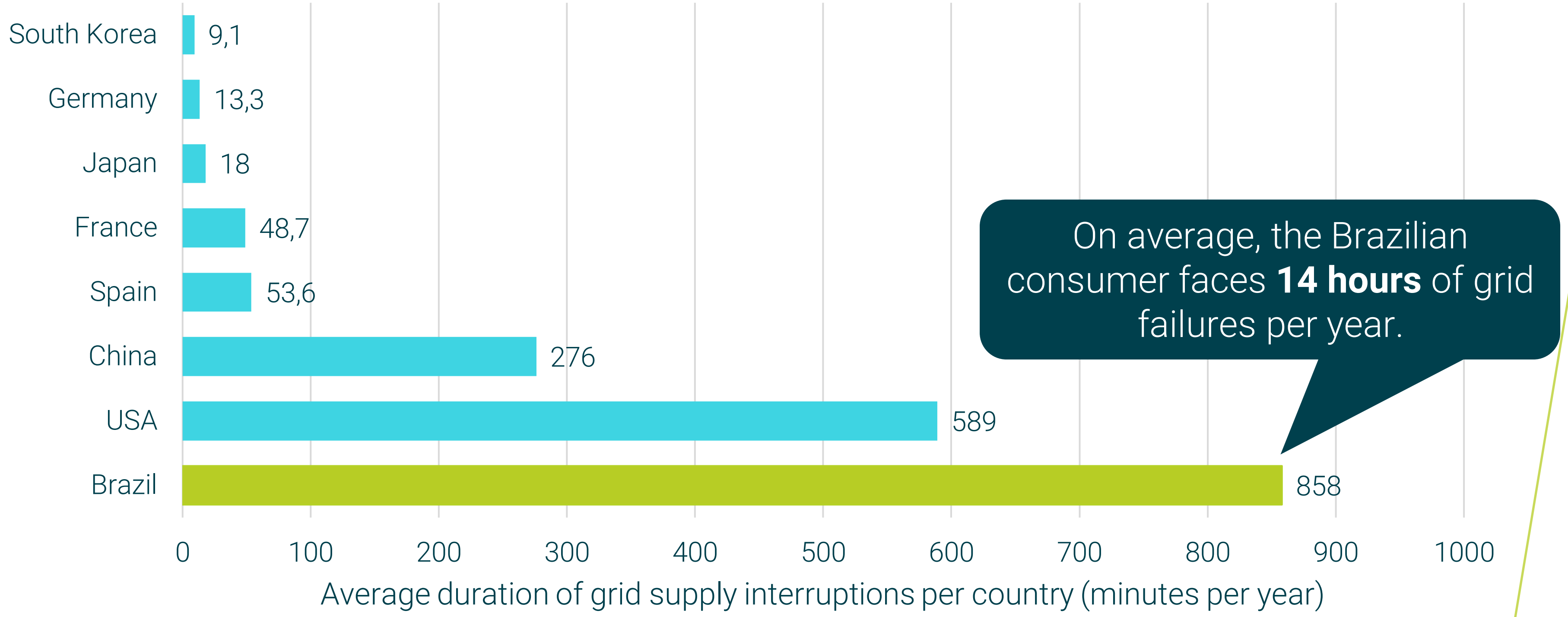
# IN-DEPTH ANALYSIS

## BEHIND-THE-METER STORAGE FOR LOW VOLTAGE CONSUMERS

| Low Voltage | |
|---|---|
| Benefits | We will analyze the benefits of small-scale hybrid systems (Solar PV microgeneration + storage) to improve the reliability of electricity supply for customers who frequently experience blackouts and other problems associated with electricity supply. |

# GRID RELIABILITY IS A SERIOUS PROBLEM IN BRAZIL

## Electricity blackouts in Brazil compared to other countries



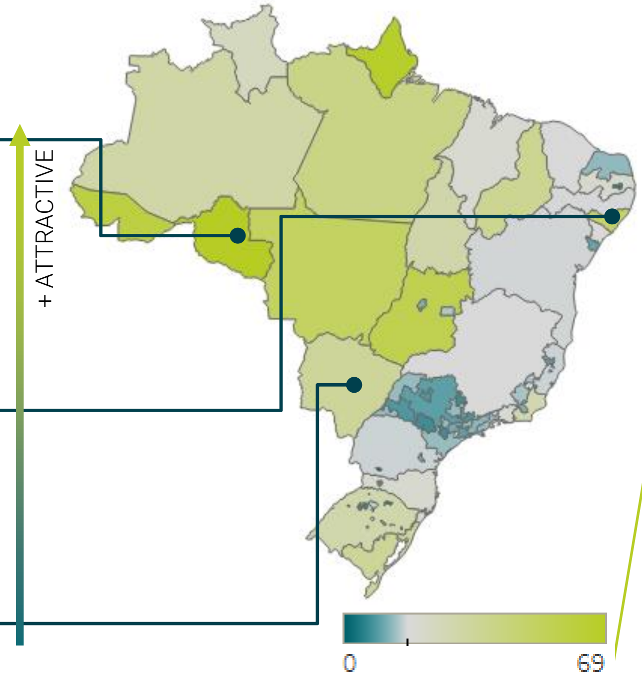

Source: VDE, ANEEL.

# REGIONS AFFECTED BY FRQUENT ENERGY BLACKOUTS

## Map of duration of power outages across Brazil

- One of the indicators for assessing the attractiveness of storage systems is the so-called **Equivalent Duration of Interruption per Customer Connection** (EDC). The **EDC** corresponds to the average number of **hours** that each customer was left without a grid energy supply during the year. The map to the right shows the average EDC for each electric utility during the year 2019. We can see that the states located in **Central**, **Western** and **Northern Brazil generally have higher EDC figures**, indicating a high demand for energy storage as a **backup service** supply in those regions. The states of Amapá and Rondônia experience the highest EDC values / worst performance, with over **68 hours** of supply interruptions that year.

| Utility | EDC (h) |
|---|---|
| Ceron | 69 |
| CEA | 68 |
| Eletroacre | 60 |
| ENEL GO | 55 |
| EMT | 51 |
| Ceal | 48 |
| Equatorial PA | 40 |
| Cepisa | 37 |
| CEEE-D | 35 |
| EMS | 34 |



# IN-DEPTH ANALYSIS
## MICROGRIDS

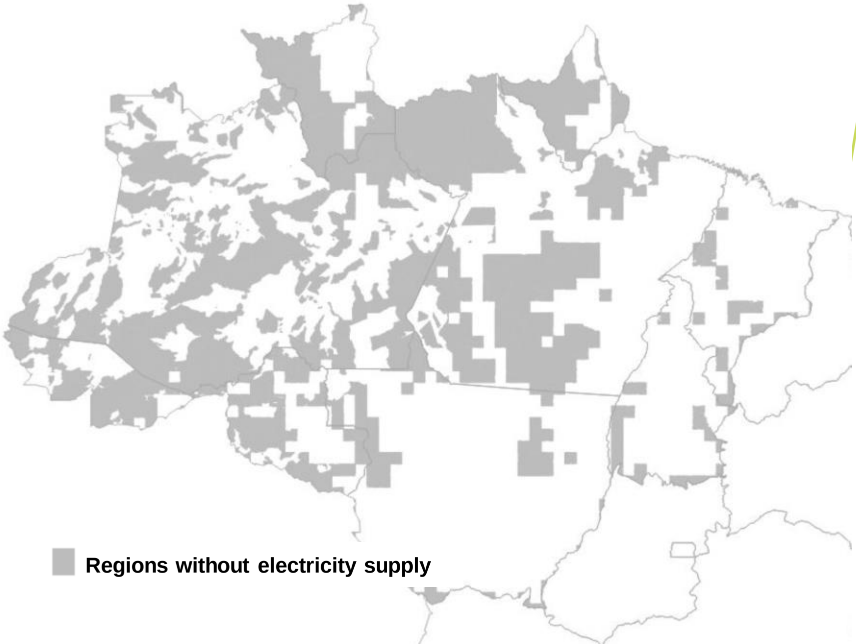
| Microgrids |
| --- |
| In the Amazon region, more than 1 million people still do not have any access to grid electricity. We will show the locations of these isolated regions in Northern Brazil, as well as the drivers facilitating the adoption of solar PV + storage hybrid solutions in those regions; |
| This segment only contemplates microgrids for individual households or small communities. |

# SMALL SCALE OFF-GRID SYSTEMS

## Renewable energy sources with storage

- According to IEMA (Institute for Energy and the Environment), around **1 million people** in the Amazon region still **do not have access to electric energy**.
- Governmental electrification programs, such as 'Luz para Todos' (Light for Everyone) and 'Mais Luz para a Amazônia' (More Light for the Amazon) will be important drivers facilitating the adoption of off-grid energy solutions for remote communities.
- The market for replacement equipment (batteries/inverters, especially replacement of lead-acid batteries) will also contribute to the growth of this segment.
- Services - especially qualified labor for installations - will also represent a significant part of the revenue stream, given the challenging conditions for accessing remote locations in the Amazon region.
- Hybrid PV + storage solutions set will be fundamental for the development of the bio-economy concept in the Amazon region.

**Areas in the Amazon region without any access to electric energy**




Source: IEMA – Instituto de Energia e Meio Ambiente.

# **IN-DEPTH ANALYSIS**
# LARGE-SCALE OFF-GRID SYSTEMS

## Isolated Micro Systems

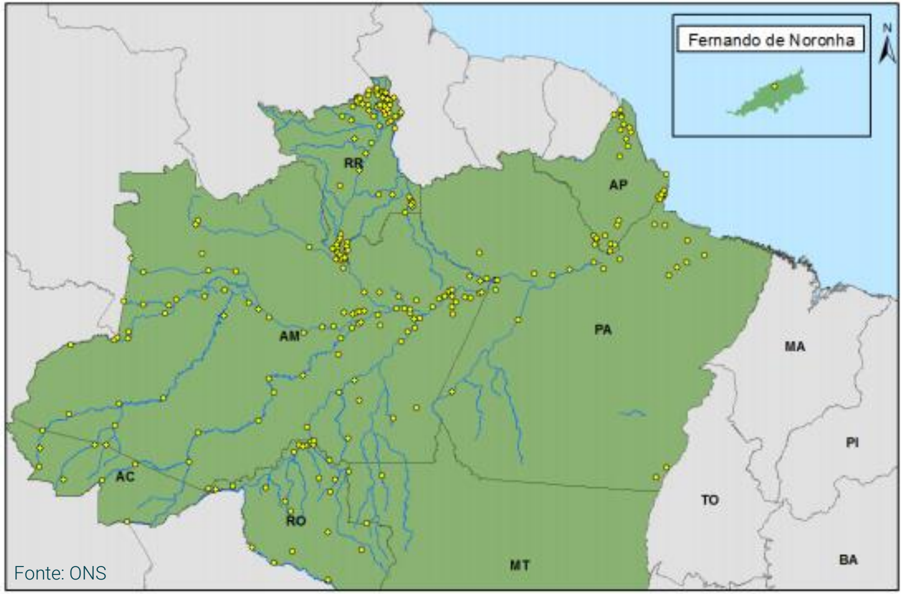
- In Northern Brazil more than 1.5 GW of Diesel generators is being operated regularly, serving isolated municipalities and large-scale energy consumers. We will evaluate the potential of reducing the consumption of Diesel fuel (and related $CO_2$ emissions) via medium and large-scale hybrid systems (energy storage + solar PV).

# MAP OF ISOLATED/OFF-GRID SYSTEMS

- According to a recent study (2019) from EPE, **271 municipalities** in Northern Brazil are not connected to the national energy grid and receive their electricity via off-grid systems. More than **3 million people** live in these municipalities.

- 97% of these off-grid systems use Diesel generators, whose fuel is being subsidized by the so-called CCC* fund. In 2018 those subsidies amounted to **BRL 6.2 billion** (approximately USD 1.2 bn).

- Hybrid storage + solar solutions will contribute to reducing these fuel costs and providing a cheaper, cleaner, and more efficient energy source for these communities.



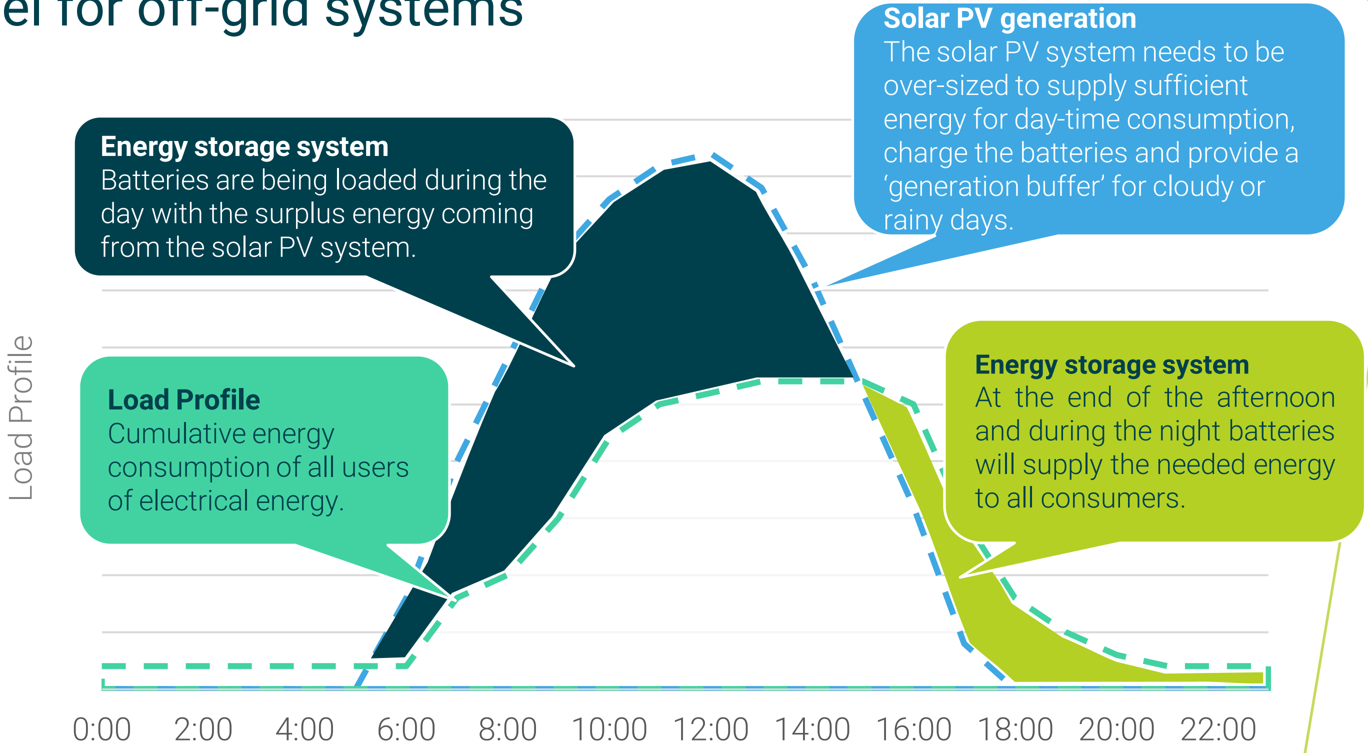
Fonte: ONS

* CCC: conta de custo de combustível (fuel subsidies for off-grid systems).

# CONCEPT OF A HYBRID STORAGE + SOLAR PV SYSTEM

## Storage + PV + Diesel for off-grid systems

- Energy storage fulfills a fundamental role by compensating the mismatch between the load profile (consumption) and solar PV energy generation.
- Diesel power generation can increase the reliability and autonomy of such off-grid systems by compensating for any generation shortfall on days with low solar irradiation.



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