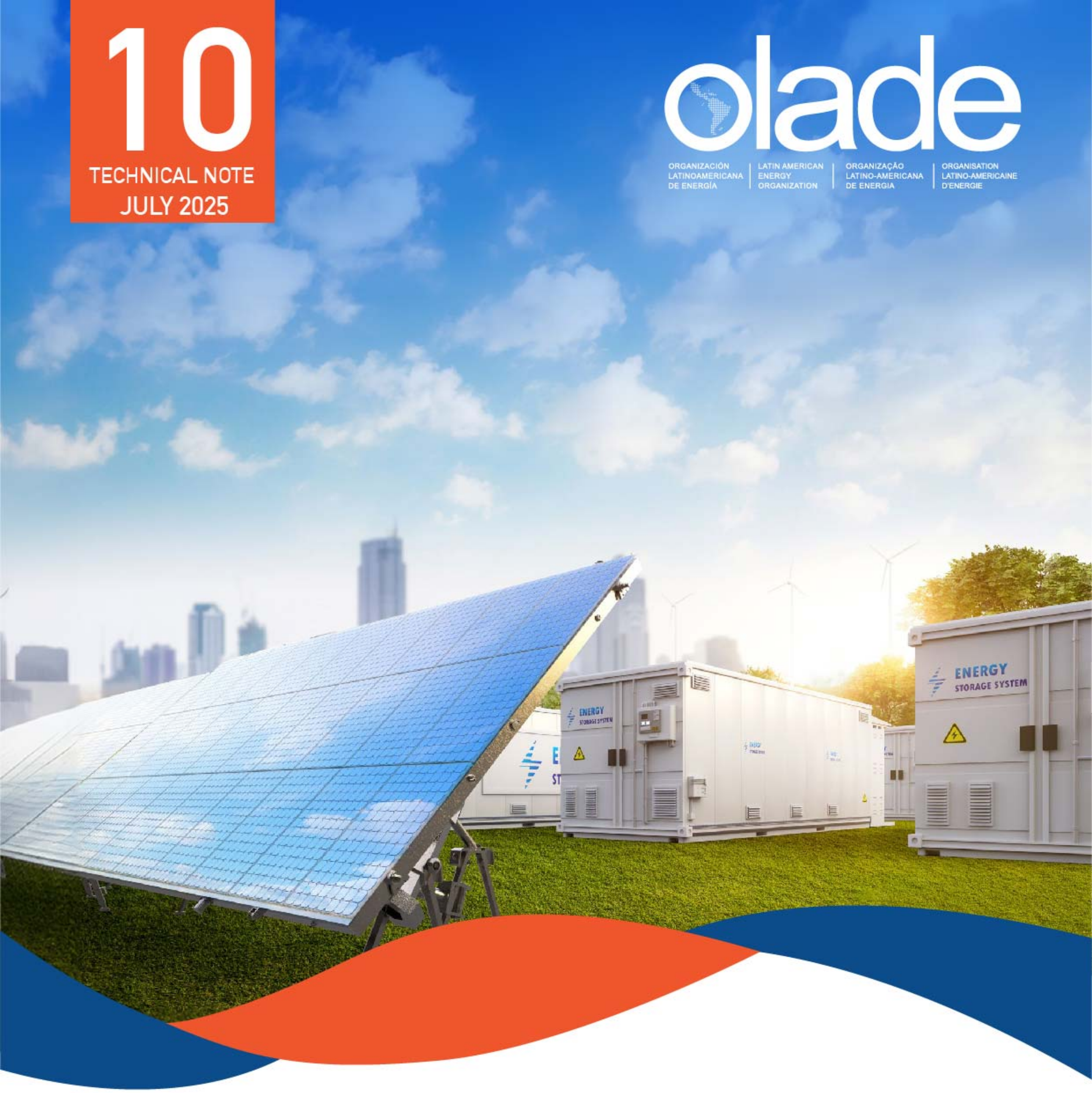

TECHNICAL NOTE Nº 10

ENERGY STORAGE IN LATIN AMERICA AND THE CARIBBEAN

Current Status, Challenges, and Strategic Recommendations

Energy Join us

This document was prepared under the guidance of
Latin American Energy Organization
(OLADE)

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Energy Storage in Latin America and the Caribbean

1. Introduction

Latin America and the Caribbean are uniquely positioned to face the energy transition, thanks to their abundant potential in renewable sources—including solar, wind, hydroelectric and geothermal. Nevertheless, harnessing this potential efficiently and sustainably depends to a large extent on the development and integration of technological alternatives that can ensure a continuous and high-quality supply across all sectors of society, with both technical and economic efficiency.

In this context, energy storage emerges as an alternative that allows the electricity generated during periods of low demand to be stored and used when the system requires it—either due to reduced generation or increases in demand. This capability is essential for managing the variability of sources such as the sun and wind, whose availability varies throughout the day and across seasons. In a region like Latin America and the Caribbean with vast renewable potential and significant climate variability, this regulatory capacity is essential to ensure the reliability of the electricity system.

In addition, the storage presents a strategic opportunity to electrify rural, remoted or insular areas where extending distribution grids is expensive or unfeasible. Through decentralized solutions based on hybrid systems (solar + batteries, for example), make it possible to deliver clean, safe and continuous energy to communities that have historically been excluded from energy access. This not only improve their quality of life but also creates opportunities for development.

From an economic perspective, Energy storage reduces dependence on fossils fuels—in many cases imported— while helping stabilize energy costs, optimize the use of existing electricity infrastructure and defer the need for costly investments in generation or transmission. Moreover, storage opens the door to new business models, including microgrids, distributed generation or the use of storage as a provider of auxiliary services in more developed electricity markets.

From an environmental perspective, energy storage contributes directly in decarbonizing the energy matrix by avoiding the use of backup thermal plants and enabling greater integration of clean sources. This makes it a critical ally for countries in the region to meet their climate commitments under the Paris Agreement and advance towards low-emission development.

To conclude, in a regional context marked by vulnerability to natural disasters, energy crises and structural inequalities, energy storage enhances the resilience of electricity systems, allowing a faster and more efficient response to emergencies, outages or supply fluctuations.

2. Energy Storage versus renewables variability

2.1. Nature of the challenge

The integration of renewable energy sources into electricity systems in Latin America and the Caribbean has delivered important benefits in terms of sustainability, emission reduction, and diversification of the energy matrix. Nevertheless, if the variable nature of these sources is not adequate and timely addressed, it can lead to economic losses and continued reliance on backup fossil plants—undermining the decarbonization objectives.

Key aspects that define this challenge include:

- **Temporal variability**: Solar power generation is limited to daylight hours and is influenced by climatic factors such as cloud cover, latitude, and seasonal changes. Wind generation is even more variable, as wind intensity can change abruptly in a matter of minutes. This variable nature complicates the scheduling and the continuous control of power generation.
- **Mismatch between supply and demand**: Renewable generation frequently does not align with peaks of energy consumption. For example, solar production peaks at midday, while demand tends to be at the highest in early morning hours and during the night—when solar is not available. This temporal mismatch underscores the need for mechanisms that can store excess generation and release it when required.
- **Difficulties in electricity planning and dispatch**: The growing participation of intermittent renewable sources reduces the predictability capacity of the electricity system, complicating the economic dispatch of generation. This uncertainty necessitates maintaining constant operating reserves or relaying on thermal plants as a backup, which undermines overall system efficiency.
- **Overgeneration and energy curtailment**: In certain scenarios—particularly during periods of high renewable production and low demand—the electricity system may be unable to absorb the energy surplus, especially in the absence of options like exporting to neighboring countries. This results in energy curtailment, where clean energy is wasted due to insufficient infrastructure to store and shift it for use during periods of greater need.

These elements highlight the need for viable solutions, among which energy storage emerges as a key tool to mitigate the effects of variability associated with non-conventional energy sources (NCRE), guarantee supply continuity and optimize the use of renewable resources in the region.

2.2. Storage role

In response to the challenges outlined previously, energy storage plays a critical role by enabling the following:

- Storing surpluses and releasing it during peak demand (e.g. batteries, compressed air, molten salts, hydrogen).
- Smoothing generation curves (*peak shaving*), to reduce the need for fossil backup plants.
- Increase renewable penetration capacity, allowing more solar or wind projects to be connected to the grid without compromising its stability.

From an operational perspective, energy storage is an extremely useful resource for operators and electricity systems, as it contributes to:

- Intermittency management: Storage helps smooth out hourly and seasonal variations of solar and wind generation, ensuring a more constant supply.
- Load shifting: Energy generated during peak production can be stored and used during times of high demand, reducing reliance on fossil sources.
- Grid services provision: modern BESS incorporate *grid-forming* functionalities, that allows black start and contributing to frequency regulation and voltage control, maintaining the system stability amid sudden changes.
- Backup and supply continuity: In isolated or rural systems, storage contributes to energy autonomy, improving the quality and continuity of service.
- Dispatch optimization: In interconnected grids, storage improves the operational efficiency of the system by reducing the need for spinning reserves and backup generation.

Therefore, energy storage should not be considered merely as a technical complement to renewable energy. It is a strategic tool that reduces dependence on fossil fuels and transforms electricity systems into more robust, sustainable and resilient structures.

Its development and integration must become a priority on the energy agenda of Latin America and the Caribbean to move towards a fair and effective energy transition, with greater speed and efficiency.

3. Energy Storage Technologies

A wide range of energy storage technologies exist—from lithium-ion batteries to more advanced solutions such as thermal, gravitational or hydrogen storage—which are revolutionizing the way energy is produced and consumed. In this context, understanding the operating principles, advantages, limitations and applications is essential to fully understand its impact on the global energy future.

3.1. Electrochemical storage (batteries)

Lithium-ion batteries are the most widely used technology due to their high efficiency and energy density. Other options include flow and sodium-sulfur batteries, which are being investigated for their implementation in large-scale storage systems.

Battery Energy Storage Systems (BESS)

Battery energy storage systems (BESS) have gained prominence in Latin America and the Caribbean, driven by technological development and declining costs. At their core, these systems store energy to be released it when required, whether for technical or economic reasons.

BESS operate by storing electrical energy in rechargeable batteries and function based on the following principles:

1. Charging: During periods of low demand or when renewable energy generation is abundant (e.g. sunny or windy hours), the system absorbs and stores energy in batteries.
2. Storage: The stored energy is retained in the electrochemical cells of the batteries, remaining available until needed.
3. Discharge: When electricity demand is high or renewable generation drops, the BESS system releases the stored energy to the power grid or specific facilities.
4. Smart Management: Modern battery storage systems are equipped with energy management software that optimizes charging and discharging to maximize efficiency and minimize costs.

Advances in BESS technology

- Next-generation lithium-ion batteries: Enhancements in energy density and reduced charging times.
- Solid-state batteries: Increased safety, extended life, and reduced risk of flammability.
- Hybrid storage systems: Combination of BESS with complementary technologies—such as thermal storage and green hydrogen.
- Integration with smart grids: Use of artificial intelligence and big data to optimize the operation of storage systems.

- Battery recycling and second life: Development of processes to reuse batteries in other applications before final disposal. Viable approaches include:
    - Reuse in lower-demand applications: Battery modules that have lost part of their capacity in industrial applications can be repurposed for less demanding uses, such as back-up in rural microgrids or residential storage.
    - Component refurbishment: the evaluation and selective replacement of cells or modules within BESS containers can extend the operational life of the system without the need for complete replacement.
    - Recycling of strategic minerals: Specialized processes for dismantling BESS systems to recover valuable materials such as lithium, cobalt, nickel, copper and aluminum would contribute to reduce dependence on mineral extraction.
    - Circular economy models: implementation of frameworks that include design for disassembly, service contracts (Battery-as-a-Service), traceability of components, and extended manufacturer responsibility.
    - Second life in community or educational settings: BESS retired from commercial use can be redeployed in educational facilities, laboratories, or community centers to provide backup power or serve as practical tools for technical education.

BESS benefits for Electrical Systems

- Grid stabilization: BESS can rapidly absorb and discharge energy, helping to mitigate fluctuations and improve the overall quality of electricity supply.
- Efficient integration of renewable energies: Facilitate the incorporation of solar and wind sources by storing the energy generated during periods of high generation and releasing it in low generation periods.
- Reduced operational costs: Store energy at times of low demand and release it during peak consumption helps reduce reliance on costly and polluting generating plants.
- Increased energy security: By acting as a backup, BESS act a backup that can supply power during grid outages, improving the resilience of the electricity system.
- Participation in complementary services markets: In some countries, batteries play a critical role in providing services such as frequency regulation and voltage control.
- Use optimization of existing infrastructure: It allow investments deferral in new transmission and distribution lines, improving the efficiency of the system without requiring large grid expansions.

Figure 1 BESS Storage Plant

Components of a BESS:

A BESS consists of several key components that work together to store energy and convert it as needed.

The main components are:

Table 1 BESS basic components

Component	Functionality
Battery cells	Stores electric energy
Inverters	Converts direct current (DC) to alternating current (AC)
Battery management system (BMS)	Monitor battery performance and safety
Energy management system (EMS)	Optimize system efficiency and performance

Additional components:

1. Power Conversion System (PCS): Also known as a bi-directional inverter, is responsible for converting DC electricity from the battery cells into AC electricity and vice versa. In addition, PCS plays a crucial role in managing the charge and discharge rates of batteries based on grid requirements.
2. Transformer: The transformer increases or reduce electricity voltage levels. In a battery energy storage system, the transformer is essential to match the voltage levels of the AC generated with the requirements of the power grid or the connected load. This is essential for seamless and efficient BESS integration with the electrical system.

3. Fire suppression system: Ensures safe operation and prevents electrical fires.
4. Heating, ventilation, and air conditioning (HVAC): Regulates internal temperature for an optimal battery performance.

Applications of BESS:

The most common applications are:

1. Backup power: BESS provide a backup source during grid outages or emergency situations.
2. Peak shaving: By storing energy during off-peak hours for its use during periods of high demand, BESS help reduce the generation requirements to meet peak demand.
3. Grid forming: BESS can be used to back up the grid by providing services such as black start, frequency regulation, voltage support, and load leveling. This helps improve grid stability and reduces the need for fossil fuel-based power plants.

3.2. Mechanical Storage

Mechanical storage harness kinetic or gravitational energy to store and release electricity efficiently. In Latin America and the Caribbean, these technologies are being explored in diverse applications.

Types of mechanical storage

- Pumped storage hydropower: This technology involves pumping water to an upper reservoir during periods of energy surplus and releasing it to generate electricity at times of high demand.
- Flywheels: Systems that store energy in a high-speed rotating disk, allowing for rapid delivery of power when needed.
- Gravitational storage: An emerging technology that uses the lifting and lowering of heavy masses to efficiently store and release energy.

3.2.1. Pumped storage hydropower (PSH)

Pumped Storage Hydropower (PSH) is one of the most mature and widely deployed technologies for large-scale energy storage. It operates by pumping water from a lower reservoir to an upper reservoir during periods of energy surplus on the grid. When demand increases, the stored water is released and flows through generating turbines that produces electricity.

Consists of two water reservoirs at positioned at different heights that can generate energy as the water descends from the upper to the lower reservoir (discharge), passing through a turbine. The system also requires energy to pump water back to the upper reservoir (recharge). PSH functions similarly to a giant battery—storing energy when it’s abundant and releasing it when is needed.

Open-loop pumped storage hydropower versus closed-loop

PSH systems can be classified into two main types, open-loop or closed-loop. Open-loop PSH systems maintain a continuous hydrologic connection to a natural body of water. In closed-loop PSH systems, reservoirs are not connected to an external body of water.

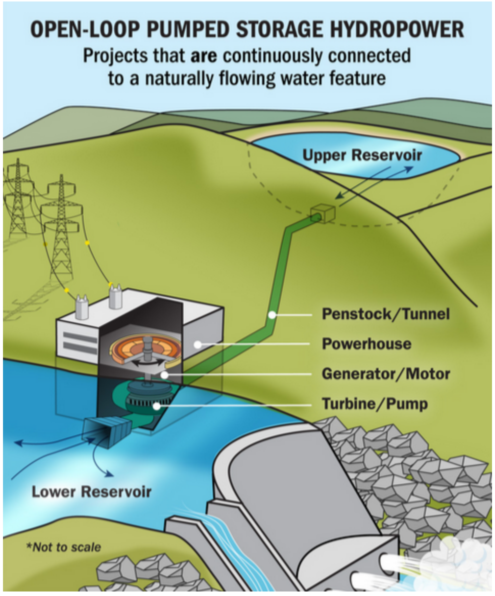

Figure 2 Open-loop Pumped storage hydropower. Source: DOE (US Department of Energy).

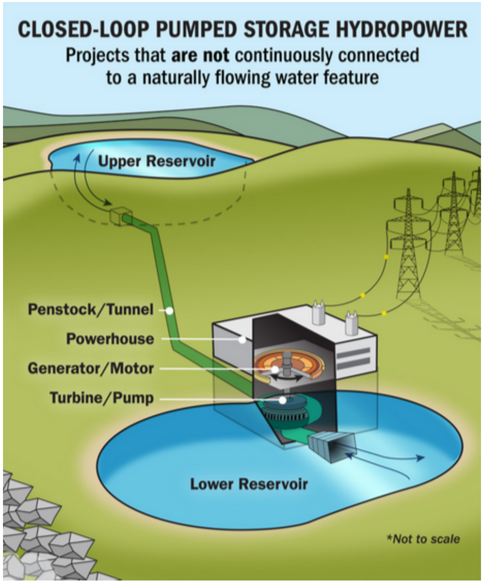

Figure 3 Closed-loop pumped storage hydropower. Source: DOE (US Department of Energy).

Open-loop pumped storage hydropower systems connect a reservoir to a water source that flows naturally through a tunnel, using a turbine/pump and a generator/motor to move the water and generate electricity.

Closed-loop pumped storage hydropower systems connect two reservoirs without running water sources through a tunnel, using a turbine/pump and a generator/motor to move water and generate electricity.

Advantages of pumped storage hydropower

This type of storage offers multiple technical, economic and environmental advantages, especially in contexts with adequate geographical resources and electricity systems with high penetration of intermittent renewable energy. Its main benefits include:

- High storage capacity and long lifespan

  Pumped storage can store vast amount of energy (ranging from hundreds to thousands of MWh) over extended periods, making it ideal for meeting sustained demands, managing excess renewable generation or responding to energy emergencies. Unlike electrochemical batteries, it's not limited to daily or short cycles.

- Proven efficiency and reliability

Pumped storage hydropower plants offer a cycle efficiency (stored energy vs. recovered energy) of between 70% and 85%, making them among the most efficient large-scale storage technologies solutions. They also have a long lifespan, exceeding 40 years, with minimal levels of degradation and high operational reliability.

- Stability and support to the electrical system

These systems can provide essential ancillary services to the grid, including frequency regulation, voltage control, spinning reserves, and black start capability. Their fast response allows the system to be stabilized in the event of sudden fluctuations or failures in other generation sources.

- Complementarity with renewable energies

Pumped storage hydropower acts as a natural reservoir for surplus solar or wind energy, especially useful at periods of low demand or grid saturation. This helps to maximize the use of clean sources and reduce the curtailment of unused renewable energy.

- Low relative environmental impact

Although the construction of reservoirs can involve significant impacts, pumped storage projects that reuse existing hydroelectric infrastructure or closed-loop artificial reservoirs have a relatively low environmental impact compared to new dams or thermal plants. Moreover, pumped storage systems do not emit direct greenhouse gases during operation.

- Reduced operational costs

Once constructed, pumped storage systems have very low operating and maintenance costs compared to technologies that require chemical or fuel inputs. This makes them economically attractive in the long term, particularly in interconnected systems with high energy demand.

Pumped storage hydropower represents a mature, efficient and high-capacity solution for the support of electrical systems with increasing penetration of renewable energy. In Latin America and the Caribbean, the development of PSH offers important opportunities to enhance the electricity system flexibility, reduce emissions, and strengthen regional energy security—especially in countries with existing hydropower infrastructure and favorable geographical conditions.

3.2.2. Flywheel storage

Flywheel energy storage, also known as rotational or kinetic energy storage, is a technology that stores and releases electrical energy by spinning a disk or cylinder at high speed. This type of system converts electricity into kinetic energy through an electric motor that accelerates the flywheel, and then reconverts that energy into electricity when the flywheel decelerates, using the same motor acting as a generator.

While flywheels do not offer the same storage capacity as batteries or pumped storage, they offer extremely high efficiency, near-instantaneous response times, and a long lifespan. These features make them particularly useful in applications that require short-term grid stability and regulation.

Main Technical Features:

- Ultra-fast response time: flywheels can absorb or deliver energy within milliseconds, making them an ideal solution for frequency regulation and voltage stabilization in power grids.
- High power density: This system can provide large amounts of energy in short periods, although their storage capacity in terms of duration (total energy) is limited.
- Long lifespan and low maintenance: Since flywheels doesn't have chemical reactions, they exceed 20 years of lifespan, without significant degradation over cycles.
- High conversion efficiency: Flywheel systems achieve efficiencies between 85% and 95%, thanks to low friction (when operating in a vacuum or with magnetic levitation) and a robust mechanical design.

Most common applications:

- Real-time frequency regulation.
- Stabilization of electric transport systems (such as trains or metros).
- Uninterruptible Power Supplies (UPS) for data centers and critical facilities.
- Support in microgrids or industrial facilities with variable loads.

Advantages:

- Immediate response to fluctuations, ideal for strengthening stability in grids with high penetration of renewables.
- High durability, no loss of capacity from charge and discharge cycles.
- Low environmental impact, as the technology involves no chemical reactions and produces no gases during operation.
- Requires little physical space, especially in urban or industrial applications.

Limitations:

- Low long-term storage capacity, making it unsuitable for extended power backup.
- High initial cost, particularly for advanced models using magnetic levitation or vacuum chambers.
- Increased mechanical complexity and the need for safety systems due to the rotational speed and the risk associated with structural failures.

Although their use in the region remains limited, flywheels could play a key role in isolated systems, microgrids or smart cities— particularly where precise frequency regulation or support for critical loads is required. Their high reliability, durability and low environmental footprint make them a valuable complementary solution to other storage technologies in specific scenarios with demanding technical requirements.

Figure 4 Energy storage flywheels from S4 Energy (Netherlands))

3.2.3. Gravitational storage

Gravitational storage is an emerging technology based on a simple physical principle: harnessing the potential energy generated by raising a mass and then converting it into electrical energy as the mass is lowered. This type of storage converts electrical energy into gravitational potential energy during periods of low demand by lifting large solid or liquid blocks, then releases that energy when the mass descends and drives a generator.

Unlike pumped storage hydropower, which requires large volumes of water and specific geographical conditions, gravitational storage systems use solid materials (such as concrete or steel) and can be installed in a wider range of locations, including urban, industrial or mining environments.

Operating principle:

The system consists of a platform or crane that uses electrical energy to lift a set of heavy masses to a specified height. When energy is required, the masses descend in a controlled manner, driving an electric generator. The amount of energy stored depends on three factors: the mass lifted, the height of the elevation, and gravity.

Advantages of Gravitational Storage:

- Durability and low maintenance: By not relying on chemical reactions or pressurized fluids, gravitational systems can operate for over 30 years with minimal maintenance requirements.
- High recyclability: The materials used (concrete blocks, steel, electric motors) are highly recyclable. This supports circular economy and environmental sustainability.
- Geographical adaptability: Unlike pumped storage hydropower, this system does not require water resources or steep terrain, allowing for installation in a wider range setting, including urban, industrial or even underground environments.
- High operational safety: With no flammable substances or toxic materials, the environmental and safety risks are significantly lower compared to other technologies like chemical batteries.
- Stable performance: The efficiency of gravitational systems is between 70% and 85% and do not experience notable degradation under continuous use.

Current limitations and challenges:

- High initial costs: the infrastructure required (cranes, support structures, solid masses) represents a considerable investment, particularly in early stages of development.
- Low energy density: to store substantial amounts of energy, heavy masses must be lifted to high altitudes, which can limit scalability in certain environments.
- Technology in the early phase of commercialization: although there are operational prototypes in Europe and the United States, gravitational storage has not yet been implemented on a large scale.

Gravitational storage offers an innovative alternative for countries aiming to diversify their energy matrix without relying exclusively on chemical batteries or hydraulic reservoirs. The sustainable and modular approach of this technology aligns with fair energy transition strategies, by generating local employment in construction and operation while minimizing environmental impact.

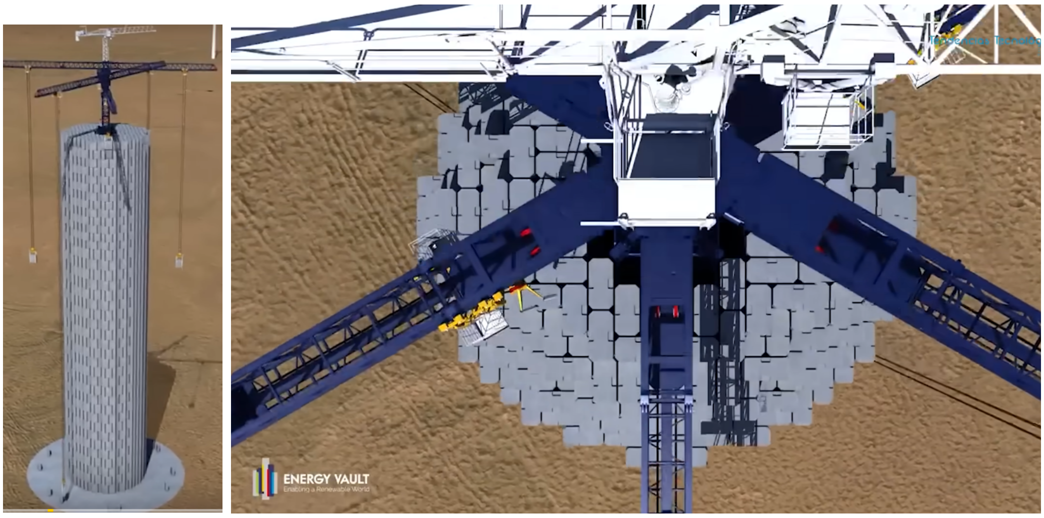

Figure 5 Energy Vault's 5MW gravitational storage prototype (Switzerland))

3.3. Thermal storage

Thermal storage consists of the accumulation of energy in the form of heat for later use. It uses materials such as molten salts, hot water, and phase-change to store thermal energy and release it as needed.

Advantages of thermal storage:

Energy savings

- Enables energy use during off-peak hours (and lower cost) and to release it when it is needed.
- Reduce consumption at peak times.

Cost reduction

- Lowers electricity bills by taking advantage of lower hourly rates.
- Reduces the need for additional generation systems during peak demand.

Improved energy efficiency

- Enhance the performance of systems such as boilers, heat pumps or air conditioning by storing thermal energy.

Contributes to sustainability

- Supports the integration of renewable sources like solar thermal by storing heat during sunny hours for later use.
- Reduce the use of fossil fuels.

Reliability and support

- Acts as a backup source in case of electrical failures or service interruptions.
- Improves the stability of the power grid if used on a large scale.

Varied applications

- Applicable across multiple sectors: Air conditioning of buildings, industrial processes, solar thermal power plants, refrigeration, and more.

Low environmental impact

- When combined with renewable energy, the environmental impact is very low.

Real applications of thermal storage

- Solar thermal power plants: Use molten salts to store the sun's heat and generate electricity even at night.
- Buildings and Air Conditioning: Ice is generated at night (low rate) and then used to cool the buildings during the day.
- District heating: Heat is stored in giant tanks to heat residential complexes or industrial facilities, hospitals, and more.

- Industry: Many industries (textile, food, paper) store heat for thermal processes.
- Solar-powered homes: Solar thermal panels heat water in tanks for use in bathrooms, cooking, or heating.

Figure 6 Cerro Dominador thermal storage system - Chile

3.4. Chemical storage (hydrogen, green ammonia)

Chemical energy storage—particularly through hydrogen and green ammonia—is an alternative with great potential to decarbonize industrial and energy sectors in Latin America and the Caribbean. These compounds allow to store renewable energy in the form of sustainable fuels that can be used in power generation, transportation, and heavy industry.

Green hydrogen

Green hydrogen is produced through the electrolysis of water using renewable energy. This process allows energy to be stored in the form of hydrogen and later used in fuel cells or turbines to generate electricity without carbon emission.

Advantages of green hydrogen:

- Zero polluting emissions: Its production or use do not generate CO_2 or greenhouse gas.
- Abundant energy source: Since is produced from water, it becomes an abundant source. Its potential becomes even greater as technological development make it possible to use seawater.
- Solves the problem of intermittency: by storing surplus solar or wind energy, it becomes a solution to the problem of intermittency.
- Versatility of use: It serves as fuel for: vehicles (cars, buses, trains and even airplanes), heating, industrial production, electricity generation.
- Alternative for complex sectors: It can replace fossil fuels in sectors that are difficult to decarbonize, such as steel or heavy transport.

Figure 7 Green Hydrogen plant- Iberdrola

Green Ammonia

Green ammonia is another renewable energy carrier produced from green hydrogen and nitrogen in the air. It is mainly used in fertilizers production, but it is also being considered as a clean fuel for maritime transport and power generation.

Advantages of green ammonia:

- Net-zero carbon emissions: When produced using green hydrogen, green ammonia produces no CO_2 emissions. It can replace gray ammonia (which does pollute) in agriculture and industry.
- Simpler storage and transportation compared to hydrogen: At moderate temperature and pressure, ammonia is easier to transport than pure hydrogen. It can be stored in existing tanks and ships.
- High energy density: Green ammonia has a high volumetric energy density, making it an option as a fuel for ships, trains, and power generation.
- Versatile applications; It can be used as agricultural fertilizer, direct fuel or raw material in the chemical industry.

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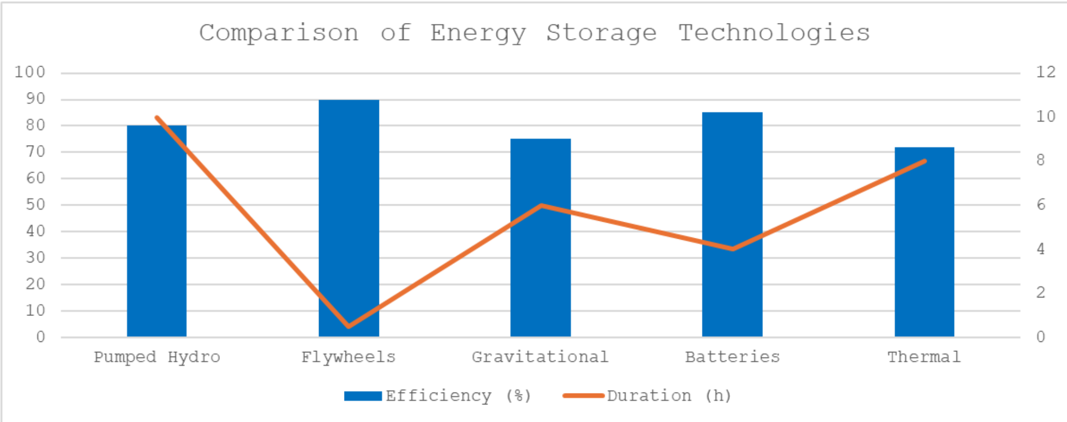
Figure 8 Ammonia and green fertilizer plant - Sweden

3.5. Storage technologies comparison

4. The following graph compares five energy storage technologies—pumped hydropower, flywheels, gravitational storage, batteries, and thermal storage—based on two key variables: energy efficiency (%) and estimated storage duration (hours).



Source: Author's elaboration

Figure 9 Comparison of Storage Technologies

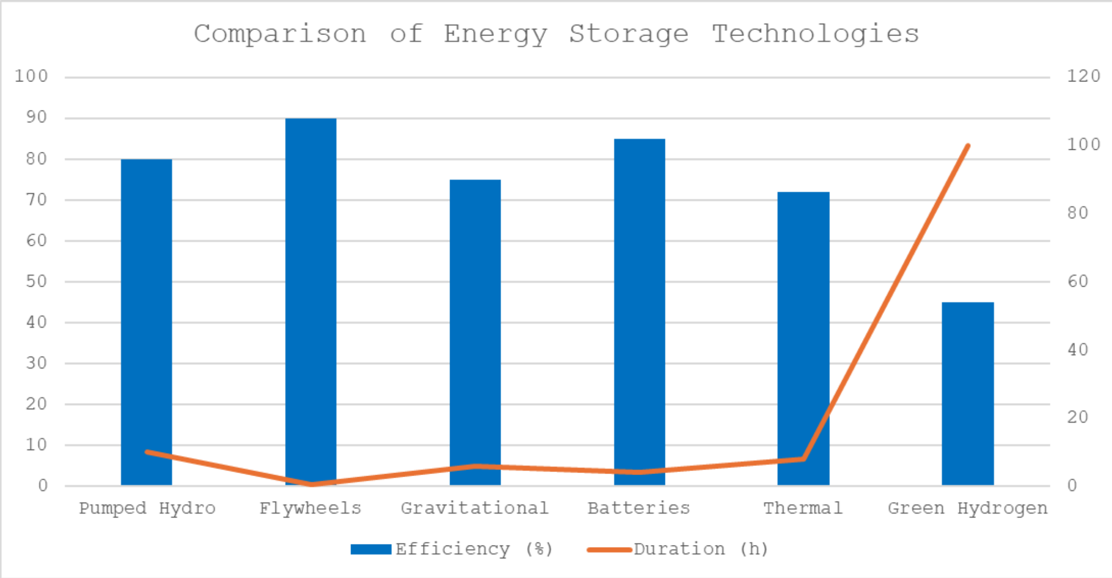
Flywheels exhibit the highest efficiency (90%), but they are designed for very short-term storage (approximately 15 minutes), making them ideal for frequency regulation and grid stabilization.

In contrast, pumped hydropower and thermal storage stand out for their high long-term storage capacity, with durations of over 8 hours. These technologies offer a balance between durability and efficiency, making them useful for daily or weekly backup in interconnected systems.

Electrochemical batteries, widely used for their versatility, provide a balance between efficiency (85%) and average duration (4 hours), making them suitable for a wide range of applications. Gravitational storage, still under development, also shows an intermediate profile in terms of duration and efficiency.

Finally, thermal storage, despite its lower efficiency (70%), stands out for its low estimated cost and extended storage capacity, making it a viable alternative for industrial applications or buildings with significant thermal demands.

If green hydrogen is included in the comparative analysis, the graph takes this form:



Source: Author's elaboration

Figure 10 Comparison of Storage Technologies including green hydrogen

The inclusion of green hydrogen underscores a key point in the storage discussion: the distinction between high-efficiency technologies and those capable of long-term energy storage. Despite its lowest energy efficiency (~40%) among the options analyzed, green hydrogen offers unmatched storage duration, enabling energy to be conserved for days, weeks or even months, making it a strategic solution for seasonal energy backup, transportation, heavy industries and clean energy exports.

Although their efficiency is lower, green hydrogen plays a complementary role: it is not a matter of competing with short-term high-efficiency technologies, but of offering large-scale and long-range storage solutions necessary to guarantee energy security in a renewable future.

There is no single superior technology. Each offers specific advantages according to the technical, economic and geographical context of application. The strategic combination of multiple storage solutions can strengthen the resilience and sustainability of energy systems.

3.6. Levelized cost of storage (LCOS)

The cost of different technologies plays an important role. A parameter that contributes to this analysis is the Levelized Cost of Storage (LCOS). This metric calculates the average cost per megawatt-hour (MWh) of energy stored and dispatched over the entire lifespan of a storage system. This indicator is essential for comparing the economic viability of different energy storage technologies.

Factors that influence LCOS:

- Cost of investment: Investment costs (materials, equipment, construction) account for a substantial portion of the LCOS.
- Operation and maintenance cost: Management, maintenance, and repair of storage systems contribute to the LCOS.

- Duration and efficiency of the system's lifecycle: Lifecycle and efficiency of storage technology also impact the LCOS.
- Load prices (load energy): If the storage is powered by renewables, the LCOS is directly affected by the prices of energy sources.

Below is a comparative table of the main storage technologies and their respective estimated LCOS for 2024:

Table 2 LCOS by Storage Technology (2024)

Comparison of LCOS by Storage Technology (2024)			
Storage Technology	**Estimated LCOS (USD/MWh)**	**Typical storage duration**	**Main applications**
Pumped storage hydropower (PSH)	30 – 100	>10 hours	Grid backup, seasonal storage
Gravitational storage	~50	4 – 8 hours	Industrial applications, grid backup
Lithium-ion batteries (Li-ion)	124 – 296	1 – 4 hours	Frequency regulation, energy arbitrage
Thermal storage	50 – 150	6 – 12 hours	Renewable integration, grid backup

Source: Author's elaboration.

Note: LCOS ranges may vary depending on factors such as geographic location, system size, financing costs, and expected lifetime.

Lithium-ion (Li-ion) batteries are currently the most widely used option for short-duration storage due to their high efficiency and decreasing costs. Nevertheless, their LCOS may increase in long-duration applications.

In contrast, pumped storage hydropower (PSH)—despite its high investment costs—remains the most mature and lowest-cost storage technology per MWh, ideal for large-scale and long-duration storage. PSH is particularly well suited in countries in the region that have hydroelectric resources for new developments, or hydropower plant infrastructure that can be adapted for this system.

4. Latin America and the Caribbean energy storage situation

In the context of global energy transition, energy storage has become an essential component to ensure the stability, efficiency and sustainability of electricity systems. Its capacity to manage the intermittency of renewable sources, optimize demand, and improve energy resilience makes it a strategic tool for developing countries. In this context, Latin America and the Caribbean face the double challenge of taking advantage of their enormous renewable energy potential while simultaneously advancing in the integration of energy storage into their national energy matrices.

The region has begun to make notable progress in energy storage, driven by the growth of solar and wind projects, a crescent interest in green hydrogen and the need to improve energy access in remote areas. Nevertheless, the pace of progress remains uneven among countries with institutional limitations and structural barriers that must be overcome. Compared to more developed regions, storage technologies are still in early stages.

4.1. Technological advances and early implementations

In recent years, several countries in the region have begun to incorporate storage systems, particularly lithium-ion batteries, along with solar and wind projects. These systems have been used to:

- Provide backup power in rural or isolated communities.
- Support hybrid microgrids in places without connection to the national grid.
- Stabilize distributed generation systems in urban or industrial areas.
- Provide ancillary services—such as frequency regulation, in partially liberalized electricity markets.

In parallel, some countries have started to include storage into their energy expansion plans and regulatory frameworks, although in most cases, incipiently

Electrochemical batteries—primarily lithium-ion—remain the most widely used energy storage technology due to their modularity, commercial availability and relative ease of installation. Exploration have also been initiated on alternative solutions, including thermal storage, pumped hydropower and green hydrogen.

Technological advances and early energy storage deployments in Latin America and the Caribbean have demonstrated that the region possesses the potential, technical capacity, and natural conditions to integrate these solutions effectively. While most current initiatives (with a few exceptions) focus on pilot phases or specific applications—such as hybrid systems, backup in isolated areas, or renewable integration—their performance has contributed to building institutional confidence and local knowledge, creating a solid foundation for a broader and more ambitious adoption.

These early experiences have played a pivotal role in adapting technologies to regional contexts, identifying operational challenges, and to generate technical capabilities in the field. Moreover, these initiatives have opened the door for new business models, financing schemes, and regulatory reforms that recognize the value of storage within the energy system.

4.2. Current limitations

Despite these advances, several limitations continue to slow an accelerated development of storage:

- Lack of clear regulatory frameworks that recognize the value and role of storage in the electricity system.
- Limited access to funding, particularly for emerging technologies and community projects.
- Weak digital and monitoring infrastructure, necessary to efficiently operate storage systems.
- Scarce specialized technical and professional training, which limits the operation, maintenance and expansion of these solutions.
- Lack of economic incentives or remuneration mechanisms for auxiliary services, which undermines the economic viability of projects.

Overall, the current constraints facing the development of energy storage in Latin America and the Caribbean unfolds within a complex outlook, where significant technological opportunities coexist with persistent structural, institutional, and economic barriers.

Nevertheless, the growing recognition of its strategic value offers a promising outlook. Overcoming existing limitations will require coordinated action among all actors, driven by robust public policies, technological innovation, and a long-term vision.

4.3. Strategic Opportunities

Energy storage presents a range of strategic opportunities for Latin America and the Caribbean, directly supporting the regional objectives of decarbonization, climate resilience, energy equity, and sustainable development.

The region offers exceptional conditions for advancing diverse energy storage solutions, including:

- Abundant renewable resources that generate usable surpluses if storage is available.
- Existing hydropower infrastructure that offers opportunities for retrofitting or integrating complementary storage.
- Availability of critical minerals such as lithium, copper and cobalt, essential for battery manufacturing.
- Geographical spaces available for mechanical or gravitational solutions.
- Growing interest in exporting green hydrogen, which requires chemical storage and associated industrial development.

Seizing these opportunities demands proactive planning, long-term vision, and political will—along with a regional approach that promotes cross-country collaboration and knowledge exchange. If local capacities, natural resources, and international support are effectively aligned, storage can play a transformative role in the region.

4.4. Installed capacity and projects in operation

Energy storage in Latin America and the Caribbean has grown modestly but steadily over the past decade, gradually stablishing itself as an essential component in the energy transition. Although installed capacity is still limited compared to regions such as Europe, Asia or North America, the projects already in operation in the region have demonstrated the technical viability and strategic relevance of storage—both for the integration of renewable energies and for reinforcing weak or isolated power systems.

As countries in the region advance their energy transition agendas and strengthen the integration of intermittent renewables, installed storage capacity is becoming increasingly relevant—in large-scale projects and distributed, community, or isolated solutions.

In 2024 and 2025, the region has seen notable progress, including:

- Chile: in 2024 Grenergy commissioned the "Oasis de Atacama" project in the Atacama Desert, with 1.24 GWh of capacity planned by the end of 2024 and a total planned storage capacity of 11 GWh using lithium-ion batteries. In May 2025, the Capricornio hybrid BESS PV project entered into operation, with a capacity of 48 MW/ 264 MWh. As of May 30, 2025, 5 storage systems are reported to be in the testing phase, representing a contribution of 571 MW of installed capacity and 2,378 MWh of stored energy.
- Brazil: According to a study by Greener, to 2024, Brazil accumulated a total of 685 MWh of installed capacity in energy storage, with 70% of this capacity allocated to isolated systems. In 2024, 269 MWh were added, representing a 29% increase compared to 2023.
- Honduras: In March 2025, the country awarded a storage project with 75 MW/ 300 MWh of installed capacity.

Despite these developments, total installed capacity in the region remains modest. Projects under development are expected to contribute significantly to the increase in storage capacity in the coming years.

Current installed capacity outlook

Availability of specific up-to-date data on installed storage capacity across the region is limited. Nevertheless, based on a data compilation from different sources, it is estimated that as of June 2025, the region has an installed storage capacity of 2.5 GW, which includes operational projects of different types:

Table 3 Estimated Installed Capacity 2025 (MW)

INSTALLED STORAGE CAPACITY IN LAC (As of June 2025)			
	COUNTRY	**BESS (MW)**	**HYDRO (MW)**
1	Argentina	17.50	974
2	Barbados	5.00	
3	Belize		
4	Bolivia	-	
5	Brasil	171.25	20
6	Chile	1,005.00	
7	Colombia	8.90	
8	Costa Rica	9.50	
9	Cuba	10.00	
10	Ecuador	-	
11	El Salvador	64.00	
12	Grenada	-	
13	Guatemala	-	
14	Guyana	23.32	
15	Haití	18.00	
16	Honduras	-	
17	Jamaica	-	
18	Mexico	192.00	
19	Nicaragua	0.20	
20	Panama	0.37	
21	Paraguay	-	
22	Peru	26.50	
23	Dominican Republic	-	
24	Surinam	9.00	
25	Trinidad &Tobago	-	
26	Uruguay	0.03	
27	Venezuela	-	
	TOTAL 2025	**1,560.57**	**994**

- Electrochemical batteries (mainly lithium-ion): Represents 60% of the total installed, mainly used in hybrid solar systems, microgrids, industrial backup and auxiliary services.
- Pumped hydropower: accounts for 40%, concentrated in countries with hydropower infrastructure, such as Argentina and Brazil.
- Thermal storage: to a lesser extent, used in solar thermal plants or in industrial applications, with relevant projects in Chile.
- Other emerging technologies such as flywheels or gravitational storage–no developments have been identified in the region.

4.5. Common trends in the region

Despite the institutional, economic, and geographic diversity across Latin America and the Caribbean, countries in the region share common trends and challenges that have shaped the pace of energy storage adoption.

- Growing recognition of storage as a key technology

Most countries have begun to incorporate storage into their national energy plans, climate policies, and rural electrification strategies. Even in the absence of specific regulation, storage is increasingly viewed as a necessary complement for the expansion of renewable energy.

- Predominance of pilot projects and isolated schemes

  Many countries have initiated demonstration projects, supported by international cooperation, particularly in rural, insular or weakly interconnected areas. These experiences have helped validate the technical and social viability of storage, but not yet scaled up to national levels.

- Electrochemical storage priority

  Lithium-ion batteries are the dominant implemented technology, driven by their modularity, market availability, and ease of installation. Other technologies such as thermal, gravitational or chemical storage (green hydrogen), are still in the early stages or under evaluation.

- Strong involvement of multilateral organizations

  Institutions such as the Inter-American Development Bank (IDB), World Bank (WBG), the Development Bank of Latin America (CAF), the International Renewable Energy Agency (IRENA), the Green Climate Fund (GCF) and the Latin American Energy Organization (OLADE), have played a crucial role in promoting storage, through financing, technical assistance and local capacity building.

4.6. Persistent regulatory challenges

The challenges reflect not only the relative novelty of this technology in energy markets, but also the need to adapt traditional regulatory frameworks to emerging paradigms of flexibility, decentralization and resilience.

- Absence of a clear legal definition of storage

  In many countries, Storage systems are not explicitly defined, it remains unclear whether storage should be classified as generation, consumption, transmission or an independent service, leading to ambiguity in its role within the electricity system.

- Lack of remuneration schemes for services provided

  Storage brings multiple benefits to the system (frequency regulation, backup, peak shaving or demand shift), but in most cases there is no mechanism that value or remunerates these services.

- Incompatibility with traditional tariff frameworks

  Regulatory systems based on large generators and centralized grids are not prepared to accommodate intermediate actors like distributed storage, which hinders their integration on a commercial scale.

- Low institutional and technical capacity

Many ministries, regulatory agencies lack the experience, trained staff, and planning tools to assess the technical-economic impact of storage and formulate specific policies.

- Weak integration into national energy planning:

  There are few electricity expansion plans that consider storage as a strategic tool.

- Investment risks due to regulatory uncertainty

  The absence of clear and stable rules creates uncertainty for investors, making it difficult to finance private projects, even when technical feasibility is evident.

4.7. Investment and financing in the sector

Access to finance is a key enabler for the expansion of energy storage. Development banks and international organizations are promoting investments in sustainable energy infrastructure.

Energy storage expansion in Latin America and the Caribbean requires not only technological and regulatory advances, but also sustainable investment models and financing mechanisms adapted to the needs of each country. Given that many storage solutions still involve high capital costs, especially when compared to conventional technologies, access to financing is a decisive factor for large-scale deployment.

4.7.1. Current investment outlook

In the region, investment in energy storage has been mostly concentrated in pilot projects or initiatives supported by international cooperation, with limited participation from private capital. Some elements that characterize the current scenario include:

- Projects financed by multilaterals organizations, such as the Inter-American Development Bank (IDB), the World Bank, CAF and the Green Climate Fund.
- Participation of bilateral cooperation—such as USAID, GIZ, JICA, AECID—in rural, insular or vulnerable area initiatives.
- Private investment remains incipient, due to a lack of clear business models, regulatory risks and poorly defined returns.
- Predominance of electrochemical technologies (batteries), due to their lower technological risk compared to other solutions (green hydrogen, gravitational or thermal storage).

4.7.2. Most used financing sources

The main sources of financing currently identified in the region include:

- Multilateral organizations: Finance projects through concessional loans, grants, and climate development funds.
- National development banks: Offer lines of credit or guarantees for clean energy and storage projects.

- International climate funds: such as the Green Climate Fund, the Clean Technology Fund (CTF), and the Adaptation Fund, which prioritize projects that deliver environmental and social co-benefits.
- Public-private partnerships (PPPs): Some countries have explored models of co-investment between governments, local companies and international developers.
- Community or cooperative financing: Particularly in rural areas, where local associations have co-financed microgrids with battery backup.

4.7.3. Barriers to attract investment

Despite growing interest, several persistent barriers continue to limit the flow of capital into the storage sector:

- Regulatory uncertainty: The absence of stable and predictable regulatory frameworks increases the perceived risk for investors.
- Limited understanding of viable business models: Many financial actors still do not understand the technical and economic value of storage, making it difficult to structure profitable projects.
- High capital costs (CAPEX): Particularly in emerging technologies or when importing equipment is required.
- Weak institutional capacity to structure bankable projects: Many governments lack the expertise to develop technically robust and financially viable proposals.
- Limited access to reliable technical data: which prevents accurate risk assessments and effective mitigation schemes from being designed.

4.8. Future trends in renewable integration

The energy transition in Latin America and the Caribbean is evolving rapidly, driven by decarbonization commitments, the need to modernize electricity infrastructure, and the growing competitiveness of renewable energy. In this context, energy storage is set to assume an increasingly leading role—not only as technical support, but also as an enabler of new models for generation, distribution and consumption. The following trends highlights the direction that the region will follow in coming years respect to the integration of storage with renewable sources:

1. <u>Expansion of large-scale hybrid projects</u>

Its expected a sustained growth of hybrid projects that integrate renewable generation (solar, wind) with battery storage or other technologies, particularly in countries with high solar irradiation and consistent wind resources. These projects will not only increase the installed renewable capacity, but also enhance dispatchability, reduce curtailment and give greater security to the electricity system.

2. <u>Adoption of long-life batteries and new technologies</u>

Technological innovation is advancing toward long-life batteries, such as redox flow, sodium-sulfur and solid-state batteries, which offer greater storage capacity for extended periods (6–12 hours). This will facilitate the integration of variable renewables into larger grids. Their adoption will also support critical applications such as hospitals, industrial centers, and entire cities.

3. Promoting thermal and chemical storage

Alongside electrochemical batteries, thermal storage and green hydrogen are emerging as a complementary option for managing renewable surpluses, particularly in areas with high solar radiation and low demand density. These technologies will enable large-scale energy storage and for longer periods, supporting industrial use and future export of clean energy.

4. Digitalization and intelligent control of renewable systems

The future of renewable integration is closely tied to the digitalization of the electricity system. Digital technologies, such as artificial intelligence and the Internet of Things (IoT), will improve efficiency in the management of stored energy.

Advances in control, sensorization and data management technologies has enabled the integration of artificial intelligence (AI), blockchain, and the Internet of Things (IoT) into storage systems. These innovations make it possible to perform some tasks such as:

- Prediction of the optimal charge and discharge status.
- Automated preventive maintenance.
- Traceability of the stored energy origin.
- Intelligent interaction with dynamic tariffs and electricity markets.

For the immediate future, an expansion of the following is expected:

- Energy Management Systems (EMS).
- Advanced weather forecasting.
- IoT devices and smart grids that will allow a more dynamic and efficient operation of storage together with renewables, both in centralized and decentralized grids.

5. Decentralization and End-User Empowerment

The decline in the prices of solar and storage systems will strengthen the distributed generation model with battery backup. This enables households, businesses, and small industries to:

- Generate, store and consume their own energy.
- Participate in local energy markets.
- Actively contribute to grid stability.

This will open the way to energy communities, dynamic tariffs and "prosumer" models, where storage will be a key element.

6. Storage participation in electricity markets

In the medium term, storage is expected to:

- Participate directly in wholesale energy markets.
- Offer ancillary services such as frequency control, rapid response, and backup.
- Be remunerated through adapted and competitive tariff schemes.

This will make its large-scale implementation more economically viable and attract greater private investment.

4.9. Distributed storage and microgrids

The traditional energy model—centered on large-scale generation plants connected to centralized transmission grids—is giving way to a more flexible, decentralized and resilient approach. In this emerging model, distributed storage and microgrids play an increasingly important role. This shift is particularly relevant for Latin America and the Caribbean, where there are historical challenges related to electricity coverage, service quality, and climate vulnerability, which can be effectively faced through local and smart energy solutions.

4.9.1. Distributed storage and microgrids

Distributed storage refers to the installation of small- and medium-scale energy storage systems located near the point of consumption (e.g., in homes, businesses, public buildings, or rural communities). Unlike centralized systems, distributed offers several advantages:

- Increase the energy autonomy for end users.
- Reduce the load on the main grid.
- Facilitates the integration of renewable distributed generation (such as solar panels).
- Improve the quality and continuity of the electricity supply.

Microgrids are localized energy systems that combine generation (e.g. solar or wind), storage and consumption within a stand-alone grid which can operate connected to the main grid or in isolation. Their main advantage is their ability to ensure a continuous power supply even when the general grid fails, making them ideal solutions for:

- Remote rural areas.
- Islands and insular communities.
- Critical infrastructure, such as hospitals, schools, or disaster response centers.
- Community sustainable energy projects.

4.9.2. Strategic Benefits

Distributed storage and microgrids are not only technical solutions to improve the efficiency and reliability of the power supply, but also offer strategic benefits of great impact.

- Energy resilience: Ability to maintain supply during emergencies or grid outages, reducing the vulnerability of energy systems.
- Loss reduction: by generating and consuming locally, these systems minimize energy losses.

- Support for rural areas: Strengthening the autonomy of isolated communities and their resilience to extreme weather events.
- Community empowerment: Contributes to democratize the access to energy by encouraging the active user participation, cooperatives or municipalities in the management of their energy and creating new economic opportunities at the local level.
- Environmental sustainability: Allows an orderly transition to renewable energy at the local level.

The strategic value of these solutions constitutes key tools for energy inclusion, sustainability and equitable territorial development in the region.

4.9.3. Expansion challenges

Despite their great potential to transform energy access in Latin America and the Caribbean, the expansion of distributed storage and microgrids faces a series of technical, regulatory, financial, and institutional challenges:

- Lack of specific regulations that define and regulate the use of distributed storage and the operation of microgrids.
- Tariff schemes poorly adapted to prosumers.
- Limited access to financing for small community projects.
- Deficit of local technical expertise for installation, operation and maintenance.
- Need for digital platforms and smart management technologies.

4.10. Technological innovation in storage

The evolution of energy storage is closely linked to technological innovation, which continues to unlock new possibilities in terms of efficiency, scalability, sustainability and cost reduction. These innovations not only address the technical needs of the power system, but also expand the possible applications of storage in sectors such as industry, mobility, agriculture, critical infrastructure and domestic consumption.

Storage technological innovations are profoundly transforming the global energy outlook. For Latin America and the Caribbean, adopting and adapting these technologies will be crucial to diversify the energy matrix, improve security of supply, and moving towards more flexible and sustainable electricity systems. Achieving this will require strengthening local research, promote the technology transfer and create favorable environments for the early adoption of innovative solutions. In this context, storage will evolve from being merely a support tool to become a driver of structural change in the region.

In Latin America and the Caribbean, keeping pace with these trends will be essential to design public policies, investment strategies, and energy solutions that are competitive, resilient, and adapted to the regional context.

4.11. Research and development initiatives

Research and development (R+D) is a fundamental pillar to promote energy storage solutions adapted to specific needs, resources and realities of Latin America and the Caribbean. In a global context marked by rapid technological progress, regional R+D initiatives allow the generation of local knowledge, develop specialized technical capacities and the promotion of high-value innovations. These efforts are key to enhance the technological and energy autonomy of the region.

Although investment in R+D for storage remains limited compared to other regions of the world, several countries have begun to develop projects and programs that integrate universities, research centers, energy companies and state agencies, working on new storage solutions adapted to the specific needs of the region.

4.11.1. Priority areas of research in the region

The most active and promising lines of research in Latin America and the Caribbean include:

- Electrochemical battery improvement: adaptation of lithium-ion technologies to local climatic conditions, and the development of batteries with materials abundant in the region (e.g. sodium or Andean lithium).
- Thermal storage for industrial and solar applications: Particularly in countries with high solar radiation such as Chile, Mexico or Peru.
- Green hydrogen and chemical energy vectors: research on the production, storage, transport and application of hydrogen in sectors such as mobility, industry and electricity generation.
- Intelligent energy management systems (EMS): Development of optimization algorithms, neural networks and digital platforms to integrate storage with renewables and smart grids.
- Battery recycling and second life: programs to reduce the environmental impact of storage, the reuse of electric vehicle batteries, and the promotion of circular economy.

4.11.2. Barriers to strengthen regional R+D

Despite growing interest in energy storage and the specific research progress in Latin America and the Caribbean, the development of robust scientific and technological innovation capacities in this field still faces obstacles and barriers that hinder the consolidation of sustainable and competitive R+D ecosystems in the region.

- Low public and private financing dedicated to energy R+D.
- Weak coordination between universities, research centers and the productive sector.
- Insufficient infrastructure of specialized laboratories and advanced equipment.
- Limited access to international storage cooperation networks.
- Gaps in technical training and incentives to retain young talent.

4.12. Diversification of storage technologies

The transition toward more sustainable, resilient, and decentralized energy systems demands a technological diversification of energy storage—one that can respond to different operational contexts, specific demands and territorial profiles. While lithium-ion batteries currently dominate the market due to their technological maturity and wide availability, no single storage technology can address all the diverse needs of the regional electricity system. Diversification not only improves technical performance and energy security, but also reduces costs, optimizes local resources, and reduces environmental impacts.

Given its vas climatic, geographic, and socioeconomic diversity, Latin America and the Caribbean require a comprehensive strategy for technological adoption, combining multiple types of storage according to the intended use, the scale of the system, and the conditions of the territory.

4.12.1. Benefits of a diversified technology portfolio

In response to the growing demand for flexible, sustainable and context-specific energy solutions, maintaining a diversified portfolio of storage technologies offers some advantages:

- Adaptability at different scales: from home systems to industrial plants or national grids.
- Technological complementarity: For instance, fast-response batteries for ancillary services and thermal or chemical storage for long-duration backup.
- Resilience in response to market disruptions or logistical constraints: such as shortages of lithium or other key inputs.
- Efficient use of local resources: taking advantage of the solar, geothermal, hydro or biomass potential of each country or region.
- Reduction of environmental impact through technologies with reduced ecological footprint or with greater recycling and reuse options.

4.12.2. Criteria for strategic technology adoption

To implement an effective diversification strategy, countries should consider:

- Local energy demand profile (residential, industrial, agricultural, and others).
- Geographical and climatic conditions (solar radiation, access to water, existing infrastructure).
- Investment, operation and maintenance costs, comparing the levelized cost of storage (LCOS).
- Availability of local technical capabilities for installation, operation, and technical support.
- Environmental impact and life cycle, considering recyclability and waste management.

5. Recommendations and Strategies for the future

5.1. Development of clear policies and regulations

The development of energy storage is essential to accelerate the incorporation of renewable energy in the region. Nevertheless, it faces barriers and regulatory gaps that must be identified and effectively addressed.

For energy storage to scale across Latin America and the Caribbean, it is crucial to establish specific, clear and modern regulations, adapted to new technologies and the strategic role that storage can play in the energy transition. Well-designed regulations can foster development by starting with small projects that contribute to local capacity building.

Among the aspects that can be handled through regulatory frameworks are the following:

- **Legal definition of storage**: It is essential that energy laws recognize storage as an activity of the electricity system. Some countries already define it as an "enabling technology" for the energy transition, but in many others, storage is not even mentioned and even less defined in the regulations. It is key to specify whether the storage functions as a generator, consumer, auxiliary service or whether it constitutes a distinct category, which would be the most desirable.
- **Remuneration and market participation mechanisms**: Stablish clear rules that allow storage systems to be adequately compensated for the services they provide (e.g. grid stabilization, rapid response) and can compete on equal terms with other technologies. For instance, storage services can be remunerated as a “secondary reserve", "frequency control", or "deferred dispatch".
- **Tax or financial incentives:** Regulatory frameworks should consider tax exemptions, access to green finance or soft loan, and subsidies for pilot or community projects, similar to the support provided in many countries with solar panels.
- **Technical and safety standards**: The establishment of standards for the design, installation, operation and recycling of lithium batteries, thermal storage and hydrogen storage, fundamental to ensure safety of both the electricity system and users.
- **Interconnection and grid access:** Regulatory frameworks should define the requirements for connecting storage systems to the grid and what technical requirements they must meet. Allowing small systems (residential or community) to sell stored energy to the grid (net billing or net metering) as a mechanism to develop distributed generation.
- **Regulation for multiple uses (multi-use or stacking):** Enabling the same storage system to support the grid, consume and generate energy, offer several services and be remunerated accordingly. This maximizes their profitability and efficient use.
- **Institutional coordination and energy planning:** The incorporation of storage into national energy plans. Establish competencies so that the regulatory agencies or technical bodies within ministries or state secretariats can supervise

its development. Promote synergies with electric mobility, renewable energies and energy efficiency.

5.2. Economic and financial incentives

To accelerate the adoption of energy storage technologies in Latin America and the Caribbean, it is essential to stablish a robust, accessible and adapted to national and territorial realities framework of economic and financial incentives. Given that storage still represents a significant investment in terms of initial cost (CAPEX), and their profitability depends on market structures that are still developing, incentives can play a decisive role in stimulating demand, reducing risks, and encouraging private and community sector participation.

A strategic approach to incentives and their correct implementation, not only improves the competitiveness of storage against conventional technologies, but also enables innovative business models, strengthens energy resilience and promotes social inclusion in the energy transition.

To ensure a lasting impact, these incentives must be aligned with sustainable development goals, integrated into national energy policies and designed with a territorial and inclusive approach.

Recommended Types of Incentives

- **Tax incentives**
    - Exemption from VAT and import tariffs for technological equipment and components.
    - Tax deductions for investment in storage or integration with renewables.
    - Tax credits for distributed generation with energy backup.

- **Grants and public funds**
    - Direct subsidy programs for pilot or community projects.
    - Energy innovation funds for emerging storage technologies (e.g. second-life batteries, green hydrogen, thermal).
    - Special discounts for installations in vulnerable areas or with low energy coverage.
    - Establish competitive awards and grants for startups, universities, and tech centers.

- **Access to preferential financing**
    - Green credit lines or international climate funds with reduced rates.
    - Partial guarantees or hedge funds to reduce uncertainty in investments.
    - Leasing schemes or energy service agreements (ESCOs) with storage included.

- **Market mechanisms**
    - Payments for ancillary services (frequency, voltage, reserve capacity) provided by storage systems.

   - Specific or differentiated auctions for hybrid or energy-backed projects.
   - Dynamic rates or net billing that recognize the value of storage at the residential or commercial level.

5.3. Research and development investment

Investment in research and development (R+D) is a strategic pillar for positioning Latin America and the Caribbean not merely as consumer of storage technologies, but as an active actor. Promoting local innovation not only allows solutions to be adapted to the technical, climatic and social realities of the region, but also strengthens technological autonomy, promotes green industrialization and generates high value-added knowledge.

It is recommended that countries in the region:

- Gradually increase public and private investment in R+D applied to energy storage, including emerging technologies such as flow batteries, thermal storage and green hydrogen.
- Strengthen collaboration between universities, research centers, the productive sector, and State agencies, by promoting national and regional consortia aimed at developing concrete solutions.
- Establish dedicated funds to energy innovation, with specific lines for storage and their integration with renewable energies and smart grids.
- Promote international cooperation in research, through agreements, technical exchanges and active participation in global knowledge networks.
- Support the training and retention of researchers and specialists, by stablishing scientific career programs, funding, and professional development opportunities.

Only with a clear commitment to innovation will it be possible to build a robust, competitive and resilient technological base—one that accelerates the adoption of storage and contributing to a truly sovereign, inclusive and sustainable energy transition.

5.4. Infrastructure expansion and grid modernization

For energy storage to become an effective tool in the energy transition of Latin America and the Caribbean, it is essential that the countries of the region make decisive progress in expanding and modernizing their power infrastructure. Current grids—often designed for a centralized, unidirectional, fossil-based system—must be adapted to integrate bidirectional flows, distributed generation, distributed storage, and smart energy management.

It is recommended that governments and grid operators:

- Prioritize investments in smart, resilient, and digitalized power grids capable of real-time interaction with storage technologies.
- Conduct optimization studies of their power systems to determine the actual needs for storage systems as the best option from a technical and economic standpoint.

- Incorporate energy storage, according to their needs, into national grid expansion plans, considering it not only as operational support but also as strategic infrastructure.
- Develop microgrids in rural, island, and hard-to-reach areas, leveraging their potential to provide continuous, stable, renewable-based supply.
- Promote interoperability between technologies and systems through technical standards, open platforms, and capacity building for technical personnel.

Strengthening infrastructure and the power grid not only enables the deployment of storage but also improves service quality, reduces losses, enhances energy security, and amplifies the social and environmental benefits of the energy transition.

5.5. Training and education of human talent

The development of energy storage in Latin America and the Caribbean cannot be consolidated without a strong foundation of qualified human resources. The transition to more sustainable, decentralized, and technologically advanced energy systems demands new technical, scientific, regulatory, and management competencies—which are not yet fully covered in several countries across the region. The education and training of skilled professionals and technicians is a critical enabling factor for the successful implementation, operation and maintenance of storage solutions at different scales.

To establish energy storage as a pillar of the energy transition in Latin America and the Caribbean, sustained and decisive investment in the training of technical and professional human talent is essential. The shortage of skilled personnel constitutes a structural barrier that limits the projects implementation and the efficient operation of emerging technologies.

It is recommended that governments, in coordination with educational institutions, technical training centers, companies in the sector, and regional and cooperation bodies:

- Develop specialized training programs in storage technologies (electrochemical, thermal, chemical, digital), integrating up-to-date and practice-oriented content.
- Promote public-private partnerships for dual training that combine theory with field experience and respond to the real demands of the energy labor market.
- Foster the inclusion of women, young people, and vulnerable communities in training programs through scholarships, incentives, and territorialized access.
- Strengthen the institutional capacity of universities and technical centers to become regional leaders in energy innovation and training.
- Take advantage of international cooperation to support academic exchanges, technical training stays and teacher training in emerging technologies.

Only through a comprehensive capacity-building strategy will it be possible to ensure that the region has the human capital necessary to design, implement, operate and scale storage solutions adapted to its specific contexts—while also fostering green employment and strengthening regional technological sovereignty.

5.6. Promotion of public-private partnerships

Public-private partnerships (PPPs) offer a unique opportunity to mobilize resources, share risks, and scale innovative solutions in the energy storage field in Latin America and the Caribbean. When properly structured, these partnerships can facilitate the implementation of technologically advanced projects, promote local job creation, and ensure long-term operational sustainability. Nevertheless, their success depends on building mutual trust, shared objectives, and stablishing transparent and stable regulatory frameworks.

It is recommended that governments in the region:

- Establish clear and predictable legal and contractual frameworks that provide legal certainty for investors while safeguarding the public interest.
- Identify strategic storage projects where public-private collaboration can deliver greater social, environmental and economic impact.
- Promote co-financing mechanisms, tax incentives and risk guarantee that make projects viable in key areas such as rural electrification, urban resilience, and renewables integration.
- Foster spaces for technical and strategic dialogue among public institutions, private companies, local communities, and international organizations, to co-develop roadmaps that align capabilities, financing, and innovation.
- Strengthen institutional capacities to formulate, negotiate and supervise PPPs in the energy sector, ensuring their efficiency, equity and sustainability.

The promotion of public-private partnerships (PPPs) should be understood not merely as a financial mechanism, but as a transformative strategy for collaboration. These partnerships enable the alignment of efforts, accelerate the energy transition and generate shared value for society as a whole.

5.7. Promotion of distributed storage and microgrids

Distributed storage and microgrids are essential solutions to ensure reliable, sustainable and resilient access to energy—particularly in rural communities, insular territories and areas with low coverage or weak power grids. These technologies make possible to democratize energy generation and management, empower end users, reduce dependence on fossil fuels and increase local energy autonomy. Nevertheless, their expansion requires specific public policies that recognize their strategic value and the particular territorial conditions where they impact is greatest.

It is recommended that governments in Latin America and the Caribbean:

- Explicitly include distributed storage and microgrids into their regulatory frameworks and electrification plans, recognizing them as central elements of energy transition strategies.

- Establish differentiated incentives for community projects or projects in non-interconnected areas, including subsidies, access to soft loans, and technical assistance.
- Simplify administrative and regulatory processes for the installation and operation of microgrids, adapting them to local contexts.
- Encourage the participation of local governments, cooperatives, community associations and social organizations in the design, management and monitoring of these solutions.
- Promote territorialized technical training programs, to ensure that communities can operate, maintain, and take ownership of installed systems.

Fostering distributed storage and microgrids is not only an effective technological solution—it is also a strategy for energy inclusion, territorial development, and climate justice. These solutions can accelerate the transition to a more equitable, resilient, and sustainable energy models across the region.

6. Conclusions

As storage gains traction in the region, it is becoming a strategic and inevitable pillar for the energy transformation in Latin America and the Caribbean. In a regional scenario marked by the abundant renewable energy resources, the pressing need to close access gaps in isolated areas and the urgency to improve energy systems resilience in the face of increasingly intense and frequent effects of climate change; Storage emerges not merely as a technological solution, but as a foundational enabler to develop more sustainable, inclusive and resilient solutions.

Technologies such as pumped storage hydropower, battery storage systems (BESS), thermal storage, and chemical storage with green hydrogen are proving to be viable and sustainable solutions. Their development in the region is in a process of growth, led by a group of countries that have made significant progress in establishing clear regulatory adjustments that facilitate the implementation of innovative projects with high potential for replication across the region.

Although the region has made important steps in terms of regulation, pilot projects implementation, and the incorporation of the issue into their energy agendas, several significant barriers persist: fragmented regulatory frameworks, high initial investment costs, weaknesses in electricity infrastructure, limited training of human talent, and low investment in research and development.

Nevertheless, numerous opportunities have also been identified that must be considered. These include the development of hybrid projects that combine renewable energy with storage, the expansion of microgrids in non-interconnected areas, technological diversification through alternatives for pumped storage, battery storage, thermal systems and chemical solutions, and the potential to build local innovation ecosystems that contribute to the creation of value chains that serve as new drivers of social development, job creation and expanded opportunities for all—particularly for the younger population.

Collaboration among all relevant actors and sectors involved will be essential to consolidate an inclusive, secure, sustainable, and resilient energy system. In this context, an effective way to accelerate the adoption of storage in the region is through a joint agreement among countries to establish a ***regional goal.*** Such goal would serve as a reference for national actions required in normative and regulatory aspects—an essential condition to attract the attention of investors and project promoters, and allowing access to concessional credits and sources of green financing.

7. References

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