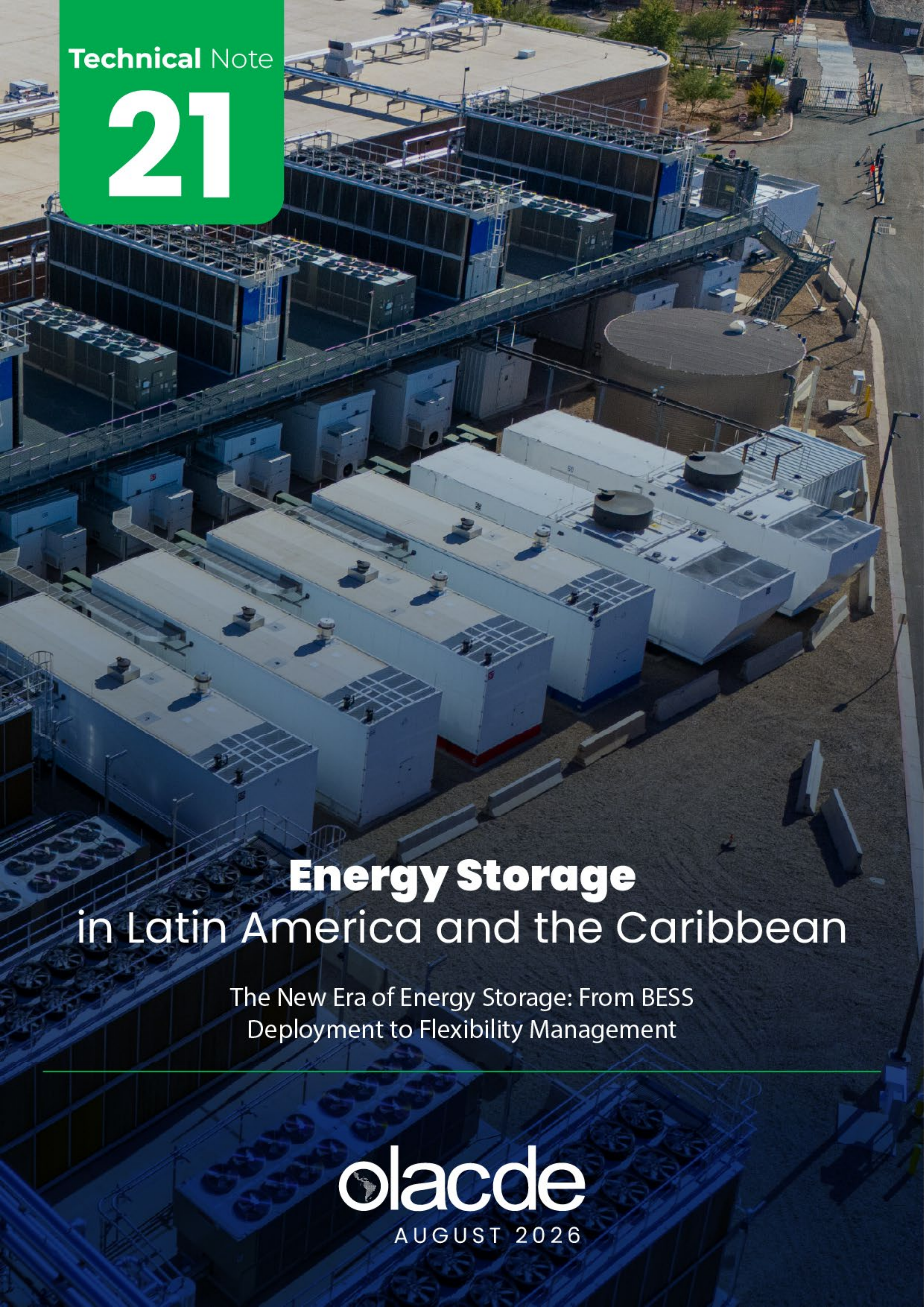

Technical Note

21

# Energy Storage in Latin America and the Caribbean

## The New Era of Energy Storage: From BESS Deployment to Flexibility Management

olacde

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This document was prepared under the guidance of
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# Energy Storage in Latin America and the Caribbean

## From the Incorporation of BESS to Flexibility Management

# 1. Introduction: a new stage for energy storage

Energy storage is not a new technology. Power systems have used different forms of storage for decades, particularly pumped-storage hydropower plants, to shift energy between periods and support system operations. What is changing is the scale, speed, and diversity of applications with which new storage technologies, especially battery systems, begin to be integrated into power systems.

The declining cost of batteries, the rapid growth of solar photovoltaic and wind power generation, and the need for resources capable of responding quickly to variations in generation and demand have created favorable conditions for this expansion. Battery Energy Storage Systems (BESS)[1] can absorb energy at certain times and release it later, while also responding within very short timeframes and providing different services required for power system operation.

This combination of characteristics explains much of the current interest in energy storage. However, its importance lies not only in the number of batteries being installed. As BESS gains scale, it begins to change the operation of the power system itself and, in doing so, some of the economic conditions that initially made its incorporation attractive.

This transformation is particularly evident in power systems with a high share of solar generation. During hours of peak photovoltaic production, there may be an abundance of energy and reduced prices, or even negative in certain markets, while a decrease in solar power generation can cause prices to rise rapidly. Batteries take advantage of this difference by charging during lower-price hours and discharging later. This shifting of energy helps reduce surpluses during some hours and increase supply during others.

But precisely because batteries respond to these price differences, when many of them begin to do so simultaneously, they can also reduce them. Storage then ceases to be merely a resource that responds to market signals and begins to become a resource capable of modifying those same signals.

This phenomenon is one of the central ideas of this Technical Note. The value of energy storage is not a fixed characteristic of the asset. It depends on the system in which it operates, its location, when it charges and discharges, the services it can provide, and the regulatory and market conditions that allow those services

[1] **BESS:** Battery Energy Storage System. In this Note, the acronym BESS is used to refer to battery systems capable of storing electrical energy and subsequently returning it to the system.

to be recognized. And those conditions can change precisely as a result of the incorporation of storage itself.

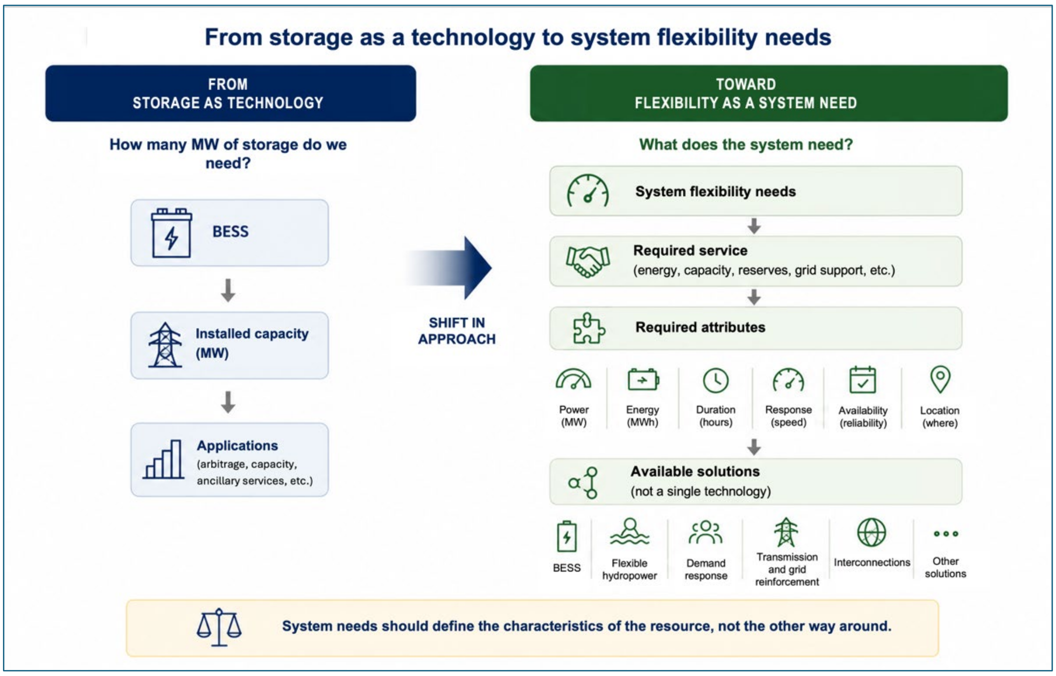
Recent experiences in Chile, Australia, and California provide insights into different dimensions of this transformation. Chile offers a particularly relevant reference for Latin America and the Caribbean due to the speed at which BESS is gaining scale within a power system with a high penetration of solar generation. Australia shows how a growing share of batteries can modify intraday price profiles and the composition of the revenues earned by these resources. California, in turn, allows us to observe how energy storage can shift large amounts of solar energy to hours of higher demand and progressively transform power system operations.

These experiences should not be interpreted as models that Latin America and the Caribbean should replicate. The region's power systems differ significantly in terms of size, structure, available resources, hydropower participation, degree of interconnection, regulation, and market organization. A battery can provide very different value in a system with abundant flexible hydropower capacity than in an island system dependent on imported fuels, even when both have similar levels of solar or wind generation.

Therefore, the relevant question for the region is not simply how much energy storage should be installed. It is first necessary to understand the flexibility needs faced by each system, what services are required, for how long and in which locations, and which alternatives can provide them efficiently. Energy storage will be one of those alternatives and, in many systems, will likely become increasingly important; however, its incorporation should respond to the needs of the system rather than become a goal independent of them.

This Technical Note analyzes energy storage from this perspective. It begins with the recent developments observed in Latin America and the Caribbean and draws on experiences from markets where BESS has reached greater scale to examine how energy storage interacts with renewable generation, power system operations, and price formation. Based on this evidence, it analyzes the evolution of its sources of value, the implications for planning and regulation, and the conditions necessary to mobilize sustainable investment in the region.

*Figure 1 From energy storage to the need for system flexibility*




The purpose is not to anticipate a single trajectory for energy storage in Latin America and the Caribbean, but rather to provide elements that can help formulate better questions and make better decisions. In a rapidly evolving technology, knowing how many MW have been installed is important; but understanding what functions they perform, what value they provide, and how that value may change as their penetration increases is even more important.

Ultimately, the expansion of BESS is moving the discussion into a new stage. The challenge is beginning to shift from adopting a technology to understanding, valuing, and managing the flexibility required by increasingly renewable power systems.

# 2. Energy storage begins to gain scale in Latin America and the Caribbean

## 2.1. From isolated projects to a new phase of expansion

The development of energy storage in Latin America and the Caribbean remains uneven and, across much of the region, is still at an early stage. However, in recent years, changes have begun to emerge that suggest a transition from relatively isolated projects toward a phase of greater incorporation of energy storage systems, particularly batteries.

The available information should be interpreted with some caution. Unlike other segments of the power sector, there is still no standardized and continuously updated regional database that allows for comparisons, under a common definition, of storage capacity that is installed, undergoing testing, under construction, or awarded across all countries in Latin America and the Caribbean. Published figures may also include different technologies, scales, and stages of development.

Therefore, rather than attempting to build a comprehensive inventory of projects at different stages of development, it is useful to distinguish between capacity that is already effectively in operation and the signals that allow us to anticipate future expansion. The former helps establish the region's starting point; the latter help us understand the direction in which it is beginning to evolve.

## 2.2. BESS capacity in operation in Latin America and the Caribbean

The recent expansion of energy storage is beginning to be clearly reflected in the capacity effectively integrated into power systems across Latin America and the Caribbean. In order to provide a comparable snapshot of this evolution, this Note considers exclusively Battery Energy Storage Systems (BESS) that are in operation, excluding projects that have been announced, awarded, are under construction, undergoing testing, or at other stages prior to commercial operation.

Under this criterion, as of August 2026, OLACDE's 27 member countries have a combined total of approximately 3,408 MW (3.4 GW) of BESS capacity in operation. This figure represents a significant increase from the approximately 1,681 MW identified in 2025 and confirms the accelerating deployment of battery energy storage in the region.

This comparison should, however, be interpreted appropriately. The update carried out for this Note did not consist solely of incorporating new systems that became operational during the most recent period. A new review of the available information for the 27 countries was conducted and, in some specific cases, it was necessary to adjust previously reported figures after verifying that certain projects that had been considered installed, or whose entry into operation had been announced, were not yet operational as of the cutoff date. For this reason, the difference between the two estimates reflects both the effective addition of new capacity and a review and refinement of the information previously used.

*Table 1 BESS capacity in operation in Latin America and the Caribbean – August 2026*

**BESS CAPACITY IN OPERATION IN LATIN AMERICA AND THE CARIBBEAN**
**As of: August 2026**

| | COUNTRY | BESS 2025 (MW) | BESS 2026 (MW) | CHANGE (MW) |
|---|---|---|---|---|
| 1 | Argentina | 17,50 | 17,50 | 0,00 |
| 2 | Barbados | 5,00 | 5,00 | 0,00 |
| 3 | Belize | — | 0,25 | +0,25 |
| 4 | Bolivia | — | 0,56 | +0,56 |
| 5 | Brazil | 171,25 | 479,75 | +308,50 |
| 6 | Chile | 1.105,00 | **2.291,00** | +1.186,00 |
| 7 | Colombia | 8,90 | 15,20 | +6,30 |
| 8 | Costa Rica | 9,50 | 15,00 | +5,50 |
| 9 | Cuba | 10,00 | 51,00 | +41,00 |
| 10 | Ecuador | — | 2,20 | +2,20 |
| 11 | El Salvador | 64,00 | 15,00 | −49,00 |
| 12 | Grenada | — | 0,00 | 0,00 |
| 13 | Guatemala | — | 0,00 | 0,00 |
| 14 | Guyana | 23,32 | 11,00 | −12,32 |
| 15 | Haiti | 18,00 | 12,00 | −6,00 |
| 16 | Honduras | — | 75,00 | +75,00 |
| 17 | Jamaica | 20,00 | 21,50 | +1,50 |
| 18 | Mexico | 192,00 | 192,00 | 0,00 |
| 19 | Nicaragua | 0,20 | 2,75 | +2,55 |
| 20 | Panama | 0,37 | 0,77 | +0,40 |
| 21 | Paraguay | — | 1,08 | +1,08 |
| 22 | Peru | 26,50 | 80,00 | +53,50 |
| 23 | Dominic Republic | — | 106,00 | +106,00 |
| 24 | Suriname | 9,00 | 12,60 | +3,60 |
| 25 | Trinidad and Tobago | 0,00 | 0,13 | +0,13 |
| 26 | Uruguay | 0,03 | 0,05 | +0,02 |
| 27 | Venezuela | 0,00 | 0,50 | +0,50 |
| | **TOTAL LAC** | **1.680,57** | **3.407,84** | **+1.727,27** |

**IDENTIFIED BESS CAPACITY IN OPERATION: MORE THAN DOUBLE THE 2025 ESTIMATE**

*Source: Own elaboration*

*Note: The table considers exclusively BESS identified as operational as of the cutoff date. It does not include projects that have been announced, awarded, are under construction, undergoing testing, or at other stages prior to commercial operation.*

Even taking these methodological adjustments into account, the trend is clear: the BESS capacity identified as operational is currently more than double that recorded in the 2025 estimate. Growth, however, remains highly uneven across countries.

Chile alone accounts for 2,291 MW, approximately two-thirds of the identified regional capacity, and is the first market in Latin America and the Caribbean where battery energy storage is beginning to reach a significant scale within the power system. Its evolution is particularly significant not only because of the scale it has reached, but also because of the pace of its recent growth. For this reason, Chile's experience is analyzed in greater detail in the following section.

At the other end of the spectrum, Uruguay provides a particularly illustrative example of how a very high share of variable renewable generation does not automatically lead to the early deployment of batteries. The system has historically managed variability through a combination of reservoir hydropower, regional interconnections, backup thermal generation, and coordinated system management. In a new stage characterized by growing demand and the expected addition of further renewable generation, UTE has begun to move forward with the incorporation of energy storage systems as an additional flexibility resource [1].

The cases of Chile and Uruguay thus illustrate two complementary aspects of the region's evolution. The former shows what can occur when the characteristics and needs of the system create conditions for the rapid deployment of energy storage; the latter serves as a reminder that the need for batteries also depends on the flexibility of resources already available and the evolution of each power system.

The review conducted for this update also reveals a signal that may be just as important as the growth in currently operational capacity. In almost all of the countries analyzed, energy storage projects were identified as either under development or at different stages prior to becoming operational. These initiatives have not been included in the reported 3.4 GW, precisely in order to maintain a consistent criterion and avoid including capacity whose effective operation cannot yet be verified.

However, the breadth of this portfolio shows that BESS development is beginning to progressively expand across an increasing number of power systems in the region. If a significant share of the projects currently under development materializes, BESS capacity in operation could significantly exceed the levels reported in this Note within a relatively short period.

The regional picture should therefore be understood as that of a process that is accelerating, but starting from very different conditions across countries. The approximately 3.4 GW currently in operation provide a measure of the region's starting point; the project portfolio identified during this review anticipates a new stage of expansion, whose scale and characteristics will depend on the specific needs, resources, and conditions of each power system.

## 2.3. Chile: the first market in the region where BESS begins to gain scale

Chile is currently the most advanced case in Latin America and the Caribbean in terms of battery energy storage and provides the clearest evidence of the transition from individual projects toward the incorporation of BESS at the system level.

The expansion of solar and wind generation, particularly in areas with abundant renewable resources and transmission constraints, has created favorable conditions for the development of energy storage. Periods of high solar generation, renewable energy curtailment, and hourly price differentials have increased the value of shifting energy from hours of abundance to periods of higher demand and prices.

This evolution is clearly reflected in the latest figures from the Ministry of Energy [2]. As of June 2026, Chile had 2,291 MW of energy storage systems in operation, with an additional 2,389 MW undergoing testing and 4,960 MW under construction. Together, these three categories amounted to approximately 9.6 GW, although it is important to distinguish between capacity that is effectively operational and capacity that is still in the process of being deployed. Beyond the 2.3 GW already in operation, the scale of projects undergoing testing and under construction shows that energy storage is playing an increasingly important role in the expansion of Chile's power system.

This development makes Chile a particularly relevant reference for Latin America and the Caribbean. It is no longer simply a matter of observing individual BESS projects, but rather of beginning to analyze what happens when energy storage reaches a sufficient scale to have a visible impact on power system operations and electricity market dynamics. International experience shows that, as their penetration increases, batteries not only respond to existing market conditions: they also begin to modify them.

For this reason, the Chilean case is particularly useful for the discussion developed in this Note. Its importance lies not only in the scale of the capacity incorporated, but also in the fact that it allows us to begin observing, within the region itself, some of the phenomena that are already manifesting themselves more intensely in markets with a higher penetration of storage.

## 2.4. New signs of expansion in other markets in the region

Although Chile represents the most advanced case in Latin America and the Caribbean, the deployment of energy storage is beginning to gain greater relevance in other countries. This evolution is not following a uniform trajectory. While some systems are moving forward with projects designed to address specific reliability or network needs, others are incorporating energy storage into broader programs for renewable generation expansion and power system modernization.

**Mexico** [3] represents one of the cases with the greatest growth potential given the scale planned for the coming years. The planning of the National Electric System foresees the deployment of 2,216 MW of battery energy storage systems by the Federal Electricity Commission (CFE) by 2030. Beyond the capacity currently installed, this scale shows that energy storage is beginning to be an explicit part of Mexico's power system expansion strategy, alongside investments in new generation and network infrastructure.

**Brazil** [4] represents a different case, in which the expansion of energy storage is beginning to be supported by a more explicit regulatory and planning framework. Although large-scale BESS capacity currently in operation remains relatively limited compared with the size of its power system, significant progress has been made during 2026 to facilitate the deployment of standalone and localized systems, while specific competitive mechanisms for new storage capacity are being prepared. This evolution is particularly significant given the potential scale of the Brazilian market and because it marks the transition from demonstration or individual projects toward a framework aimed at larger-scale developments.

**Honduras** [5] presents a different and particularly interesting trajectory for smaller power systems. The National Electric Power Company (ENEE) is developing a 75 MW / 300 MWh BESS at the Amarateca substation, equivalent to four hours of storage. The project is directly associated with transmission infrastructure and provides an example of the use of energy storage to address network needs and strengthen system reliability, rather than exclusively as a complement to new renewable generation.

**Argentina** [6] illustrates a third trajectory, based on the competitive procurement of energy storage to address system requirements. The AlmaGBA and, subsequently, AlmaSADI processes have introduced BESS as an explicit alternative for meeting capacity needs, operating reserve, and reliability. Together, the awarded projects amount to more than 1,400 MW, a considerable magnitude relative to previously existing capacity and one that, once deployed, would substantially modify the presence of energy storage in Argentina's power system. In this case, what is relevant is not only the planned capacity, but also the recognition of energy storage as a resource capable of addressing specific power system needs through competitive mechanisms.

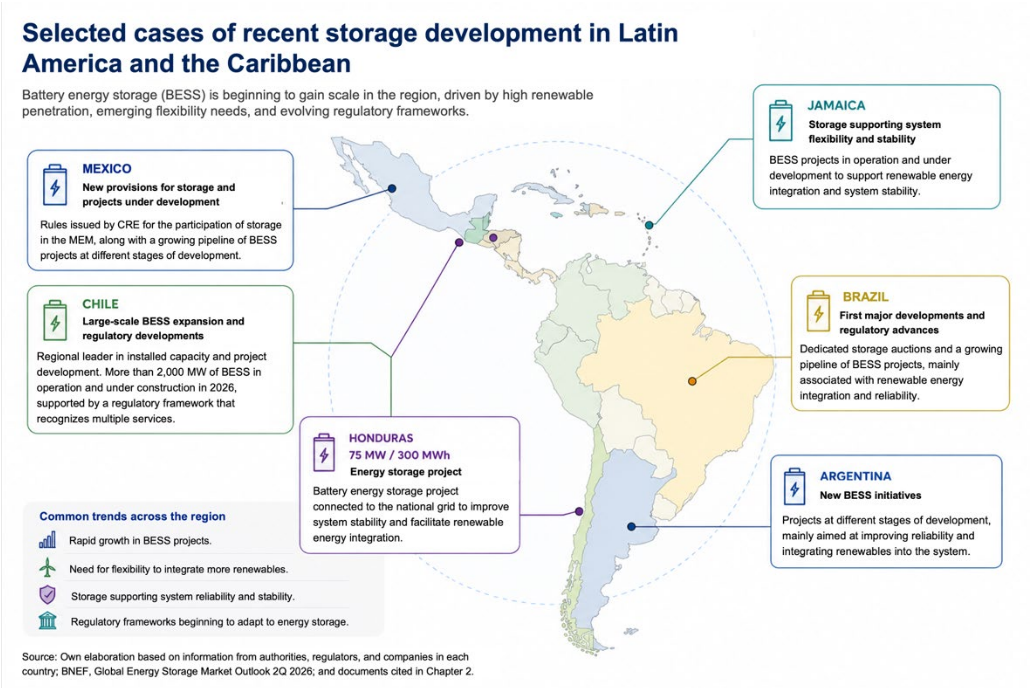
In island systems in the Caribbean, the motivations may once again be different.

**Jamaica** [7]**,** for example, has moved forward with a process to deploy 110 MW / 220 MWh of BESS associated with 220 MW of new renewable generation. The combination of renewable generation and energy storage responds to the specific conditions of an island system, where increasing the share of variable energy sources may simultaneously require greater operational flexibility, and where reducing dependence on imported fuels also represents an economic and energy security objective.

These cases highlight an important characteristic of regional expansion: energy storage is not reaching all systems for the same reason or through the same model. In Mexico, it is beginning to be part of a large-scale expansion strategy; in Honduras, it is emerging as a solution linked to network and reliability needs; in Argentina, it is being incorporated through competitive mechanisms geared toward specific system requirements; and in Jamaica, it is being developed in conjunction with new renewable generation under the particular conditions of an island system.

This diversity is particularly relevant for Latin America and the Caribbean. The expansion of BESS should not be interpreted solely as the diffusion of a technology whose cost is declining, but also as the response of power systems with different characteristics to equally diverse needs. Therefore, rather than asking only how much energy storage each country is deploying, it is necessary to understand what system problem is being addressed, what service is required, and what characteristics the resource capable of providing it must have.

*Figure 1 Highlighted cases of recent energy storage development in Latin America and the Caribbean*




## 2.5. Regulatory frameworks begin to adapt to energy storage

The region's evolution is not only reflected in installed capacity or new projects. It is also beginning to be reflected in regulatory frameworks and in the mechanisms through which power systems incorporate energy storage.

This process is necessary because much of the existing electricity regulation was designed for a system in which generation, networks, and consumption performed clearly differentiated functions. Energy storage partially challenges this separation: a battery consumes electricity when charging, subsequently delivers it back to the system, and can also provide multiple services during its operation.

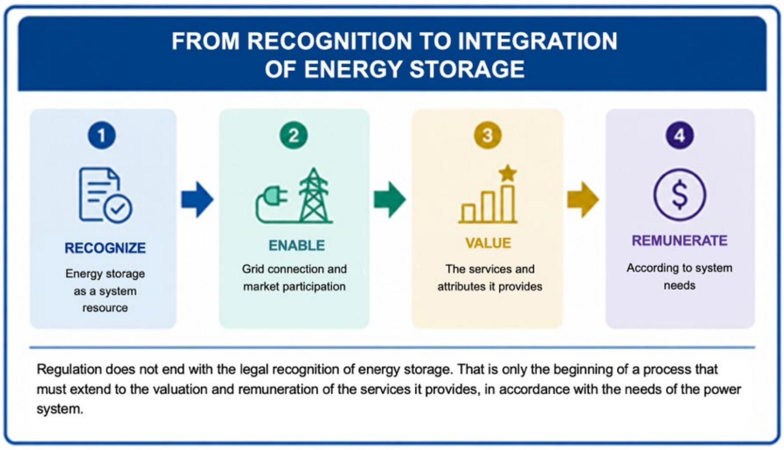
Countries are responding to this challenge in different ways. In some cases, the first step consists of formally recognizing energy storage within the regulatory framework and establishing the conditions for its connection and operation. In others, the priority lies in defining how it can participate in markets and what services it can provide. Competitive mechanisms specifically aimed at incorporating energy storage capacity are also beginning to emerge.

Brazil provides a recent example of this evolution. During 2026, the country made progress in developing specific rules for energy storage systems [8] and, in parallel, in preparing its first competitive processes specifically aimed at procuring this type of resource. In July 2026, the Brazilian Electricity Regulatory Agency

(ANEEL) opened for public consultation the tender documents for two energy storage auctions scheduled for December of the same year [4]. The mechanisms contemplate standalone BESS of at least 30 MW with a four-hour duration, designed for centralized dispatch, under 15-year contracts with supply beginning in 2028.

This case is particularly interesting because it shows how regulatory adaptation can go beyond simply recognizing the technology: energy storage is beginning to be incorporated into procurement mechanisms designed to obtain a specific system service, in this case, capacity availability.

Colombia represents another type of progress. In June 2026, the Energy and Gas Regulatory Commission (CREG) issued Resolution 101 113, which established the rules for the integration of Battery Energy Storage Systems (SAEB) into the National Interconnected System [9]. The regulation addresses aspects related to their installation, connection, operation, and commercial treatment, broadening the framework under which these resources can be integrated into Colombia's power system.




These examples show that regulatory adaptation does not consist solely of incorporating a new definition into existing regulations. As energy storage gains greater relevance, regulatory frameworks must begin to address how a resource capable of charging and discharging energy is planned, connected, and operated, how it participates in different segments of the system, and through which mechanisms it can receive revenues for the services it provides.

However, there is no single regulatory model that can be applied across Latin America and the Caribbean. Differences among wholesale markets, systems with a strong reliance on long-term contracting, vertically integrated structures, and small island systems mean that solutions must respond to the characteristics and needs of each system.

This diversity will become particularly important as energy storage deployment reaches higher levels. Recognizing batteries within the regulatory framework is only the first step; the more complex challenge lies in identifying, valuing, and adequately remunerating the services and flexibility they provide to the system.

## 2.6. A region beginning to prepare for a new phase

The available evidence indicates that Latin America and the Caribbean is experiencing a highly uneven expansion of energy storage. Nor would it be appropriate to extrapolate the pace of development observed in Chile to the region as a whole.

What is beginning to emerge, however, is a qualitative shift. On the one hand, at least one system in the region is reaching levels of BESS deployment that make it possible to begin observing its effects on system operations and markets. On the other hand, several countries are developing larger-scale projects, procurement mechanisms, and regulatory frameworks that could accelerate BESS incorporation over the coming years.

This is progressively changing the nature of the discussion:

During an initial stage, the questions were focused primarily on the technological viability of energy storage, the reduction of its costs, and the services it could potentially provide. As the technology begins to gain scale, different questions emerge:

> *What happens to power system operations when energy storage is no longer marginal? How does it modify net demand and price profiles? What happens to arbitrage opportunities when many batteries respond simultaneously to the same signals? And how does the value of energy storage itself change as its penetration increases?*

These questions are already beginning to be answered in power systems where BESS have reached a considerable scale.

For Latin America and the Caribbean, analyzing these experiences provides an opportunity to anticipate some of the challenges that will accompany the next stage of energy storage development.

# 3. When energy storage begins to transform power system operations

The effect of energy storage on a power system changes as it reaches scale. While its penetration is limited, its operation responds primarily to the conditions it encounters: renewable energy surpluses, hourly price differences, congestion, or the need for ancillary services. As its penetration increases, this relationship begins to become bidirectional: energy storage not only responds to system conditions, but also begins to modify them.

This change is particularly evident in power systems with a high share of solar generation. Battery charging introduces new demand during hours of abundant renewable generation, while discharging them shifts energy to later periods. When these movements reach significant levels, they cease to be marginal adjustments and begin to systematically modify net demand, dispatch, and the utilization of other resources.

The consequence is significant:

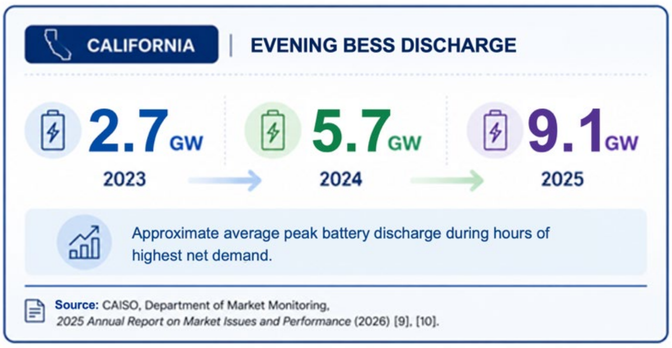
> *Energy storage ceases to be merely a resource that operates within the system and begins to become a factor that modifies its operation.*

## 3.1. From responding to the system to modifying net demand

The well-known *duck curve* helped illustrate one of the effects of high solar penetration on power system operations: a growing decline in net demand during solar generation hours, followed by a steep ramp as photovoltaic generation decreases. The large-scale deployment of energy storage is now introducing a second transformation of this curve.

Batteries act on both ends of the curve. When they charge during hours of greater solar availability, they incorporate additional demand and reduce the depth of the net demand valley. When they subsequently discharge during hours of higher demand or lower renewable availability, they supply energy and reduce the demand that must be met by other resources.

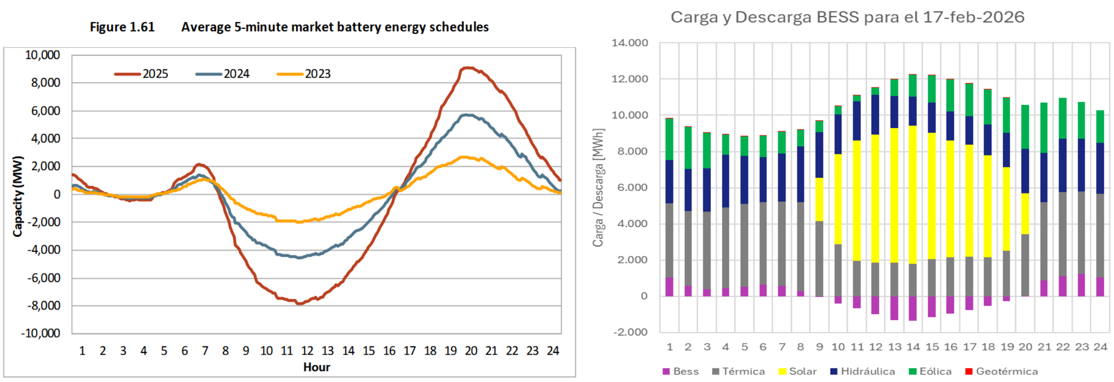
California provides a particularly clear illustration of this phenomenon. Data from CAISO's *Department of Market Monitoring* show extraordinarily rapid growth in evening battery discharge. The average peak increased from approximately 2,700 MW in 2023 [10] to 5,700 MW in 2024, and reached approximately 9,100 MW in 2025 around the hours of peak net demand [11]. At the same time, batteries increased their charging during the middle of the day, coinciding with periods of high solar generation [11].




The significance of this evolution lies not only in the growth of installed capacity. The key point is that energy storage is transferring increasingly larger amounts of energy between different periods of the day and, by doing so on a recurring basis, is modifying the hourly profile that the rest of the system must meet.

Chile is rapidly entering a comparable dynamic. The increasing operation of energy storage systems shows a pattern characterized by energy withdrawals primarily during solar hours, followed by injections, particularly after sunset. The rapid expansion of BESS is thus making it possible to shift a growing share of the energy available during the day to periods of higher net demand.

*Figure 2 Evolution of the hourly BESS charging and discharging profile in California and Chile*




(a) California (b) Chile

**Source:** Own elaboration based on CAISO, Department of Market Monitoring, 2025 Annual Report on Market Issues and Performance (2026), and Coordinador Eléctrico Nacional, The role of BESS in the development of the Chilean power system (2026).

This change makes it possible to distinguish between different stages of penetration. In an initial phase, energy storage can be considered primarily a resource that responds to system conditions. When it reaches a significant scale, it also begins to modify those conditions.

## 3.2. From surplus energy to shiftable energy

The ability to shift energy over time also changes the way periods of renewable energy abundance are managed.

In the absence of enough flexibility, high solar generation may coincide with low demand, transmission constraints, or other conditions that limit its utilization. Energy storage introduces new demand during these periods and makes it possible to shift part of the energy to later hours, when it may be more needed by the system.

This does not mean that all the energy used to charge a battery would necessarily have been curtailed in its absence. Depending on system conditions, that energy could have been consumed, exported, or could have altered the dispatch of other resources. Therefore, the broader effect of energy storage should not be interpreted exclusively as a reduction in curtailment, but rather as an increased ability to shift energy over time between periods with different conditions.

Chile is particularly illustrative in this regard. The strong expansion of solar photovoltaic generation, the geographic concentration of a significant share of renewable generation, and existing constraints in certain areas of the network have created periods of abundant energy availability and significant levels of renewable energy curtailment. In this context, the rapid deployment of multi-hour BESS introduces an additional source of flexibility.

The scale of this process is already considerable. According to Chile's Ministry of Energy, as of the end of June 2026, 2,291 MW of energy storage capacity was in operation [2], in addition to a considerable portfolio of systems undergoing testing and under construction. The projects entering the system predominantly feature multi-hour configurations, suitable for significant intraday energy shifting.

This characteristic is fundamental. A system designed primarily to provide very short-duration services can provide significant operational flexibility, but may not necessarily have sufficient energy capacity to significantly modify the balance between solar hours and subsequent periods.

Systems capable of storing energy for several hours expand this ability to shift energy over time: they make it possible to move part of the energy available during periods of high renewable generation to later hours, when it may be more needed or valuable to the system.

### 3.3. Energy storage also modifies dispatch

Shifting energy over time has consequences for the utilization of other resources in the system.

Battery discharge during certain periods reduces the generation that, in the absence of energy storage, would have been needed during those hours. The specific effect, however, depends on the structure of each system, transmission constraints, generation availability, hydrological conditions, fuel prices, and conditions for exchanges with other systems.

For this reason, it is not correct to generally assume that each MWh discharged by a battery necessarily displaces one MWh of thermal generation. The resource displaced depends on the specific conditions of each hour. In addition, the analysis must take into account that the discharged energy was previously stored, with the corresponding conversion losses.

California provides clear evidence of this transformation. During 2025, both solar generation and the use of energy storage increased, while average natural gas generation declined compared with 2024. Batteries increased their charging during solar hours and their discharging during periods of higher net demand [11].

Energy storage thus begins to modify not only when renewable energy is used, but also which other resources the system needs to use at different times of the day.

This interaction is particularly relevant in electricity markets organized around marginal dispatch. If the amount of generation required from different resources changes, and the technology that must respond during certain hours also changes, the conditions under which prices are formed may change as well. This effect is analyzed in the following chapter.

## 3.4. One MW of storage is not simply one MW

The rapid expansion of energy storage has frequently led to national targets, installed capacity, and project portfolios being expressed exclusively in terms of MW. However, power represents only one dimension of energy storage's ability to provide flexibility.

Two systems with the same power capacity can have substantially different effects if they have different energy capacities. A 100 MW/100 MWh BESS can deliver its rated power for approximately one hour, while a 100 MW/400 MWh system could do so for approximately four hours. Both have 100 MW of power capacity, but their ability to shift energy between different periods is very different.

The Chilean experience is illustrative in this regard. The systems currently undergoing testing and under construction predominantly feature multi-hour configurations, with average durations of approximately four to five hours. This reflects an important focus on intraday energy shifting, rather than solely on short-duration response services.

However, duration alone does not determine the asset's value to the system. Location is equally relevant. A system located in an area with abundant solar generation and transmission constraints may have different effects from the same system installed at another point on the network.

The system's availability at the times when the service is required also matters. A battery's rated power does not necessarily mean that this capacity will be available during a critical period; this will depend, among other factors, on its state of charge and how it has been operated beforehand.

Finally, the operating strategy determines the service actually provided. Two physically identical systems can produce different outcomes depending on the markets in which they participate, the economic signals they receive, and the constraints under which they are dispatched.

> *Therefore, an adequate assessment of energy storage must go beyond installed MW and jointly consider:*
> *power + energy/duration + location + availability + operating strategy.*

This distinction will be particularly relevant when analyzing flexibility needs and power system planning.

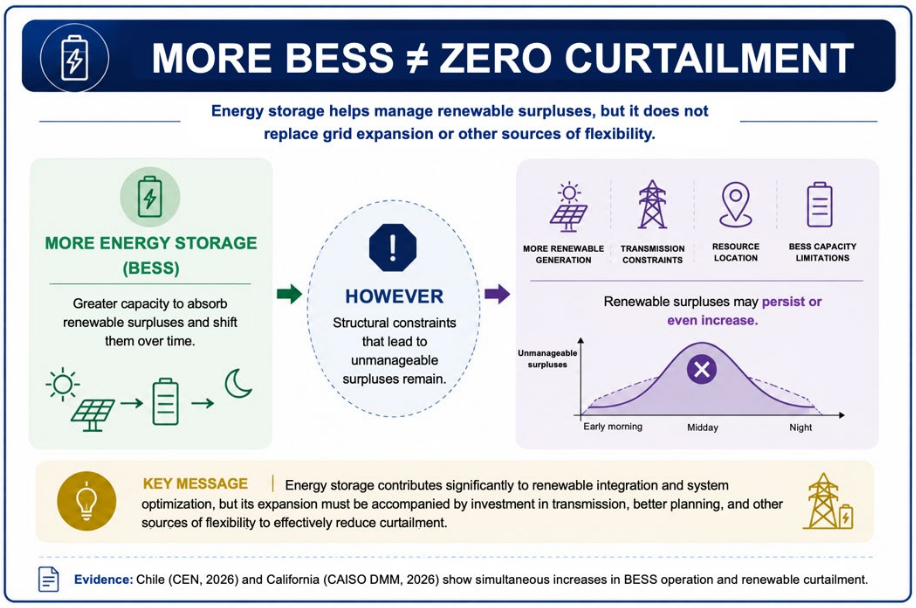
## 3.5. More energy storage does not necessarily mean less curtailment

One of the benefits commonly attributed to energy storage is the reduction of renewable energy curtailment. The mechanism underlying this claim is clear: when renewable energy is available but cannot be utilized at a given time, a battery can use part of that energy to charge and deliver it later.

However, this mechanism does not necessarily imply that aggregate curtailment must decrease as energy storage capacity increases. Recent evidence from Chile and California allows us to observe this distinction.

In Chile, strong growth in BESS operations during 2025 coexisted with still-high levels of renewable energy curtailment. Evidence presented by the Coordinador Eléctrico Nacional shows that, despite the growing contribution of energy storage to utilizing renewable energy surpluses, significant levels of curtailment persist. The Coordinador itself identifies BESS as a tool for mitigating these reductions and, at the same time, as a complement to the development of the transmission system. This means that energy storage can help absorb surpluses without necessarily resolving all the conditions that give rise to curtailment [12].

California presents a comparable outcome. Despite the rapid expansion of batteries and the strong increase in their utilization, wind and solar generation cuts increased in 2025 compared with the previous year [11].




There is no contradiction between these two phenomena. Energy storage may be utilizing increasing amounts of energy that, in its absence, might have been curtailed, and simultaneously, aggregate curtailment may increase if renewable generation is incorporated even more rapidly, if transmission constraints exist, or if surpluses occur in locations or periods where the available storage capacity cannot absorb them.

The conclusion is therefore more precise:

> *Energy storage increases the system's ability to manage and utilize renewable energy surpluses, but it does not replace the need to address other structural constraints that limit its integration.*

This conclusion is particularly relevant for Latin America and the Caribbean. Energy storage should not be considered in isolation as a solution to curtailment; it should be evaluated together with transmission expansion, the location of new generation, interconnections, demand response, and other sources of flexibility.

## 3.6. From operational change to economic change

The experience of Chile and California shows that energy storage takes on a different dimension when it reaches system-level scale. Its recurring operation modifies the net demand profile, shifts energy between periods, and alters the dispatch required from other resources. At the same time, the persistence of curtailment even in systems with growing energy storage capacity demonstrates that BESS is a source of flexibility, but does not replace other structural needs of the power system.

> *This operational transformation has an immediate economic consequence. If energy storage modifies when energy is demanded, when it is injected, and which resources must respond in each period, it also begins to modify the conditions under which prices are formed.*

# 4. When energy storage begins to transform prices

In a power system with low levels of energy storage penetration, batteries respond primarily to price signals originating from the rest of the market. When energy is abundant and prices are low, they have an incentive to charge; when energy is scarcer and prices rise, they have an incentive to discharge. This difference over time forms the basis of energy arbitrage.

However, this relationship begins to change when energy storage reaches a significant scale. If thousands of MW of batteries charge and discharge following similar patterns, they are no longer participants that are too small to influence the market. Their operation introduces significant amounts of demand during certain hours and supply during others.

> *Storage then shifts from responding to prices to participating in their formation.*

This change represents one of the most significant economic consequences of the recent expansion of BESS. Evidence from Australia's National Electricity Market (NEM)[2] illustrates this particularly clearly: during the first quarter of 2026, battery charging and discharging jointly participated in price setting in approximately 32% of intervals, making batteries the technology that most frequently played this role. One year earlier, their participation was considerably lower [13].

The significance of this phenomenon extends beyond the Australian market. It shows what can happen when energy storage ceases to be marginal: batteries begin to modify the very same economic signals that initially incentivized their operation.

[2] **National Electricity Market (NEM):** Australia's interconnected wholesale electricity market, which integrates the power systems of Queensland, New South Wales, Victoria, South Australia, and Tasmania. It is operated and administered by the Australian Energy Market Operator (AEMO).

## 4.1. From responding to prices to participating in their formation

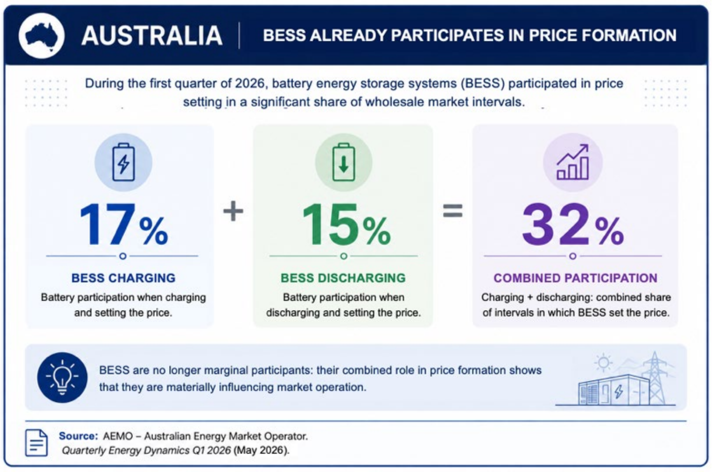
To understand this change, it is useful to briefly review, in simplified terms, how prices are formed in a competitive electricity market based on marginal dispatch.

In each interval, different resources offer energy to the market. As the amount needed to meet demand increases, offers are successively incorporated until supply and demand are balanced. The marginal resource - that is, the resource whose offer is needed to complete this balance - participates in determining the price for that interval.

A battery has a particular characteristic: it can operate on both sides of the market. When charging, it acts as demand; when discharging, it acts as supply.

As long as energy storage capacity is small, charging and discharging operations have a limited impact on the balance between supply and demand in the system and, therefore, on price formation. But when they reach several GW, they can change which resource remains in the margin and, therefore, influence the resulting price.

Australia provides particularly clear evidence. In the first quarter of 2026, battery discharging set prices in approximately 15% of NEM intervals, while battery charging did so in approximately 17%. Together, they accounted for 32%. In New South Wales (NSW), BESS charging participated in price setting in around 23% of intervals, while discharging did so in approximately 18% [13].




The change is even more evident when analyzing different hours of the day. Between 10:00 and 16:00, the frequency with which battery charging set the NEM price increased from 13% in Q1 2025 to 39% in Q1 2026. During the evening period from 16:00 to 21:00, battery discharging set the price in approximately 36% of intervals, 23 percentage points more than a year earlier. At the same time, the frequency with which gas, coal, and hydropower set the price decreased [13].

This result helps illustrate the transition:

> *Batteries first take advantage of the price differences created by the system. Once they reach sufficient scale, they begin to modify those same differences.*

To understand how this occurs, it is useful to analyze the two ends of the hourly price profile separately.

## 4.2. The lower end: renewable abundance and negative prices

Very low, zero, or negative prices are not necessarily a market anomaly. They can occur when a large amount of energy is available and demand is insufficient to absorb it, particularly during periods of high renewable generation.

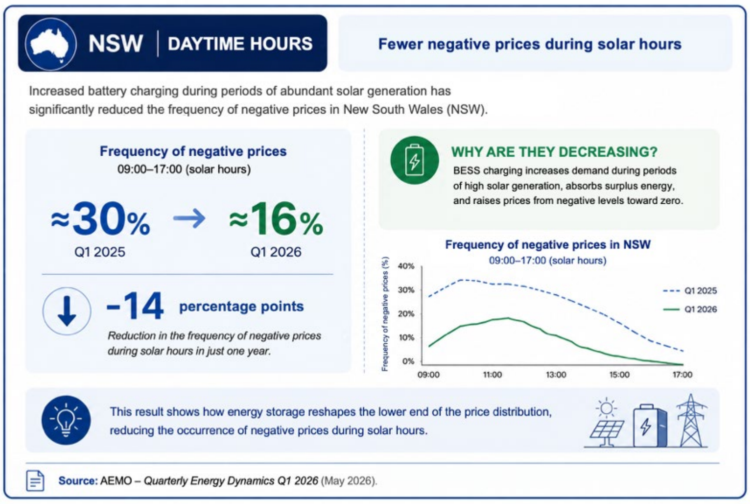
In power systems with high solar penetration, these conditions tend to be concentrated during the middle of the day. If available supply significantly exceeds the system's needs and certain generators have incentives or constraints that lead them to continue producing, prices can fall to zero or even become negative.

For a battery, these conditions represent an opportunity: it can consume energy when its market value is very low and store it for later use.

But as the amount of energy storage increases, a second effect emerges.

BESS charging introduces demand precisely during the hours of greatest energy abundance. In simple terms, batteries begin to compete for energy that previously had fewer buyers. This can raise the lower end of the price profile and reduce the frequency of certain negative price episodes.

New South Wales (Australia) provides evidence consistent with this mechanism. In Q1 2026, negative prices during daytime hours, between 09:00 and 17:00, occurred in approximately 16% of intervals, a decrease of 14 percentage points compared with Q1 2025. During the same period, the role of battery charging in price formation increased significantly [13].




However, this relationship should not be interpreted mechanically.

Australia shows significant differences across regions. The frequency of negative prices also depends on renewable energy expansion, demand, transmission constraints, interconnections, and operating conditions. Therefore, more energy storage does not necessarily imply the disappearance of negative prices.

The conclusion is:

> *Energy storage introduces a flexible source of demand that can absorb energy during periods of abundance and, when it reaches sufficient scale, can modify the frequency and characteristics of very low or negative prices.*

The effect on the other end of the hourly price profile works in the opposite direction.

## 4.3. The upper end: discharging and its impact on prices during hours of peak net demand

When solar generation declines and net demand increases, the system needs to rapidly increase available supply. In the absence of sufficient lower-cost generation, more expensive resources may be brought into operation, such as certain thermal generation units or hydropower used strategically during high-value periods.

Battery discharging introduces new supply precisely during those hours.

Energy storage can reduce the system's exposure to higher-cost marginal resources. Put simply, if a battery supplies energy during the evening peak, it can reduce the amount of generation that must come from more expensive technologies.

This effect is clearly observable in Australia. During Q1 2026, batteries shifted more than three times as much energy from the daytime period to the evening period as in the previous year and delivered, on average, around 1,115 MW during the late-afternoon and evening peak. The Australian Energy Market Operator (AEMO)[3] notes that this increased participation reduced dependence on gas-fired generation and hydropower during these periods and contributed to moderating prices [13].

The change in marginal price formation is particularly illustrative. Between 16:00 and 21:00, while BESS discharging sharply increased its participation as the marginal resource, the frequency of price setting by hydropower decreased by 13 percentage points, while that of gas and black coal decreased by 7 percentage points in each case [13].

This does not mean that a battery always reduces the price when it discharges. The outcome depends on the offers submitted, demand conditions, transmission, and the other resources available.

But it does demonstrate something more structural:

[3] **Australian Energy Market Operator (AEMO):**
operator of Australia's electricity market and power system in the markets it administers, including the National Electricity Market (NEM). Its functions include power system operations, coordination of the wholesale market, and the publication of information and analysis on the functioning of the electricity sector.

> *At sufficient scale, BESS can change which technology becomes marginal during critical hours and, in doing so, modify price formation.*

## 4.4. The combined effect: the hourly price profile changes

The two mechanisms described above act in opposite directions on the two ends of the daily price profile.

During hours of abundant renewable generation:

> BESS charges → demand increases → may exert upward pressure on the lowest prices.

During hours of higher net demand:

> BESS discharges → supply increases → may exert downward pressure on the highest prices.

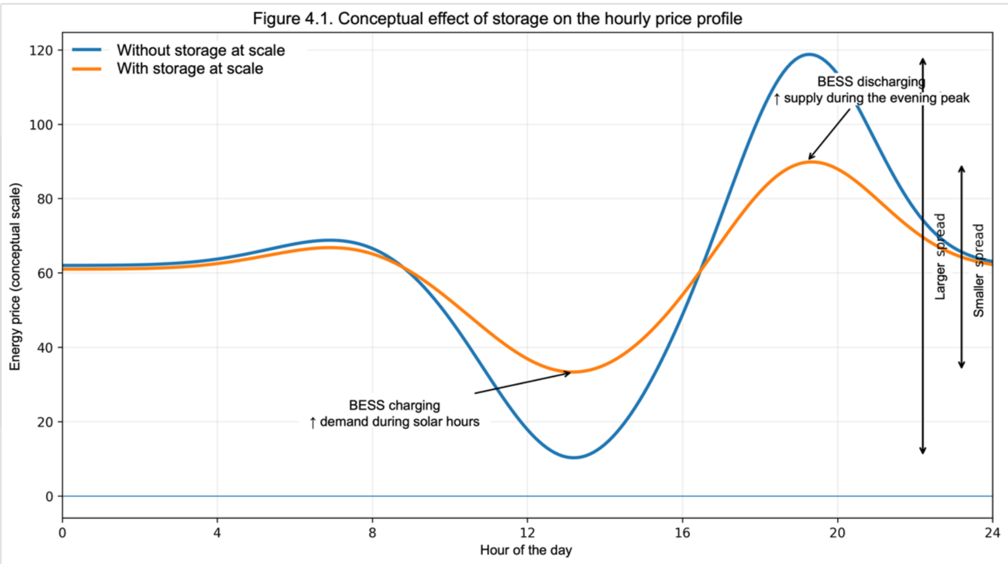
The combined effect can result in a compression of the intraday price profile.

In technical terms:

> *The increase in BESS modifies the intraday distribution of prices and can reduce the spreads used for arbitrage.*

In simpler terms, batteries buy energy when it is abundant and cheap and sell it when it is scarcer and more expensive. But when many batteries do the same thing simultaneously, they tend to raise prices during the cheapest hours and moderate prices during the most expensive hours. The difference between the two extremes then begins to narrow.

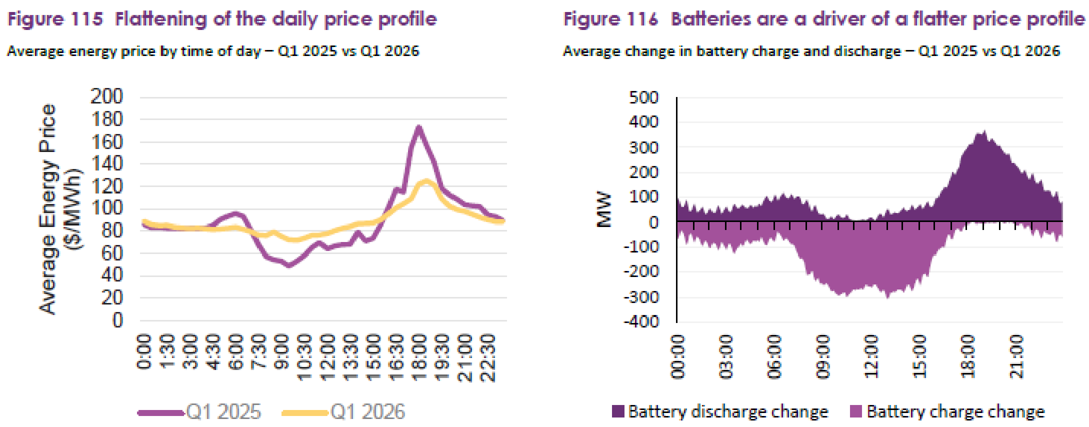
*Figure 3 Conceptual effect of energy storage on the hourly price profile*




*Source: own elaboration*

This transformation is particularly evident in Australia. AEMO has simultaneously observed greater participation of BESS charging in price formation during the middle of the day and increasing participation of BESS discharging during the evening peak. In Q1 2026, *battery price spreads* declined across most NEM regions; AEMO attributes this development to a combination of lower volatility, higher prices during the middle of the day, and lower peak prices.

*Figure 4 Energy storage contributes to modifying the hourly price profile in Western Australia*




Source: elaboration/adaptation based on AEMO, Quarterly Energy Dynamics Q1 2026, Figures 115 and 116 [13].

Panel A. Evolution of the hourly price profile, Q1 2025–Q1 2026.

Panel B. Change in the hourly battery charging and discharging profile, Q1 2025–Q1 2026.

This is precisely the phenomenon that makes it particularly relevant to analyze energy storage beyond its installed capacity. An individual battery can take advantage of volatility; a sufficiently large fleet of batteries can begin to modify it.

## 4.5. Changing the price profile does not necessarily mean reducing all prices

The evidence presented above could lead to an apparently intuitive conclusion: if batteries moderate prices during the most expensive hours, then they necessarily reduce the average price of electricity.

The relationship is more complex.

Energy storage can simultaneously exert upward pressure on some prices and downward pressure on others. When it charges during hours of abundance, it introduces additional demand and can raise prices that, in its absence, would have been lower. When it discharges during periods of scarcity, it introduces supply and can moderate prices that would have been higher.

Therefore, its most characteristic effect does not necessarily consist of shifting the entire price curve downward, but rather of modifying its distribution over time.

This distinction makes it possible to separate four concepts that are often confused:

- *hourly price profile*, which shows how prices vary throughout the day;

- *average wholesale price*, which summarizes the prices observed over a given period;
- *total system cost*, which includes costs other than wholesale energy; and
- *final consumer cost*, which additionally includes network costs, retailing, taxes, charges, and other components defined by each market.

A change in the first does not automatically or proportionally translate into changes in the others.

The Australian case shows that a reduction in prices during certain hours does not necessarily imply an equivalent reduction in the average price of electricity. In Q1 2026, the NEM's average wholesale price decreased by 12% year-on-year, to AUD 73/MWh, while battery participation increased significantly. AEMO notes that batteries contributed to lower prices by reducing reliance on gas and hydropower during the evening peak. However, the overall result also reflected changes in renewable generation, demand, resource availability, and other market conditions [13].

Therefore, it would be incorrect to conclude that the reduction in the average price was caused exclusively by energy storage.

The conclusion that is supported by the evidence is more interesting:

> *When energy storage reaches scale, it can modify the shape of the hourly price profile, reducing certain extremes and changing which resources participate in price formation.*

## 4.6. From modifying prices to modifying its own value

The Australian experience makes it possible to observe a stage that, until a few years ago, few power systems had reached. Batteries are no longer merely recipients of the signals produced by the market: their operation has become one of the factors that contribute to generating those signals.

During hours of abundance, charging introduces new demand. During hours of higher net demand, discharging introduces new supply. The result can be a reduction in price extremes and a compression of price differences over time.

But this transformation leads to an apparent paradox.

> *Arbitrage derives its value precisely from the difference between low and high prices. If the growth of energy storage contributes to reducing that difference, it can also reduce the economic opportunity that initially incentivized its deployment.*

# 5. When energy storage transforms its own value

Energy storage creates value, among other ways, by taking advantage of temporal differences in system conditions. A battery can charge when energy is abundant and prices are low, and discharge later when energy is scarcer and prices are higher. This operation makes it possible to shift energy between periods while simultaneously capturing part of the difference in value between them.

However, Chapter 4 showed that this relationship changes when energy storage reaches a significant scale. Battery charging can exert upward pressure on prices during hours of abundance, while discharging can moderate prices during hours of higher net demand. As a result, the price differences that initially made arbitrage attractive may begin to narrow.

> *Energy storage can therefore modify the very economic conditions that determine part of its value.*

This relationship introduces an important challenge for evaluating new investments. Revenues observed during the early stages of penetration cannot necessarily be projected into the future under the assumption that market conditions will remain constant. As new capacity enters the system, system operations, prices, and the opportunities available to subsequent investments change.

The recent experiences of Australia and California make it possible to observe this process from two complementary perspectives: the progressive compression of arbitrage opportunities in the energy market and the evolution of other markets, such as ancillary services.

## 5.1. From shifting energy to shifting value

The physical function of a battery is relatively simple: to store energy at one point in time and deliver it later. Its economic value, however, depends on when each of these operations takes place.

Consider a simplified example. If a battery can charge when the price is USD 20/MWh and discharge when it reaches USD 100/MWh, there is a gross difference of USD 80/MWh between the two periods. This difference, or *spread*, creates an arbitrage opportunity.

In practice, the calculation is more complex. Energy losses during the charging and discharging cycle, operating costs, battery degradation, and specific market conditions must all be taken into account. But the principle remains: *the greater the difference between the value of energy when charging and discharging, the greater, in general terms, the economic opportunity for arbitrage.*

Energy storage does not create that initial difference. It finds it in the system.

High solar generation can contribute to lower prices during the middle of the day, while the decline in that generation and the increase in net demand can raise them a few hours later. The battery takes advantage of this difference by shifting energy from a lower-value period to a higher-value period.

Therefore, energy storage can be understood not only as a mechanism for shifting energy over time, but also for shifting value between periods.

This distinction is important because it helps explain the phenomenon that emerges when many batteries begin to perform the same operation simultaneously.

## 5.2. Value to the system and asset revenue are not necessarily the same

Before analyzing this phenomenon, it is useful to distinguish between two concepts that are often used interchangeably: the value that energy storage provides to the system and the revenues that its owner can obtain.

A battery can generate different benefits. It can shift energy to periods of greater need, participate in ancillary services, reduce peak generation requirements, help manage congestion, or improve the utilization of renewable generation.

These benefits represent different forms of value to the system.

However, for that value to translate into revenue for the owner, there must be a mechanism through which it can be remunerated: energy prices, ancillary services markets, capacity or reliability payments where they exist, contracts, or other mechanisms established by the regulation and design of each market.

Therefore:

*Value to the system ≠ revenue captured by the asset.*

The distinction is not merely conceptual. It has implications for investment. A project may provide a valuable service to the system without there being a sufficient economic signal to remunerate it. Conversely, a market signal may generate high revenues during a given period without those revenues remaining constant as competition to provide the same service increases.

This distinction will be particularly important in the following chapters, when we analyze planning and regulatory design.

## 5.3. The arbitrage paradox

Arbitrage has a particularly interesting characteristic: when energy storage reaches sufficient scale, it can contribute to reducing the economic opportunity it is taking advantage of.

The mechanism is the same as the one analyzed in Chapter 4.

When batteries charge during periods of low prices, they introduce new demand and can exert upward pressure on those prices. When they discharge during periods of high prices, they introduce new supply and can exert downward pressure on them.

In technical terms:

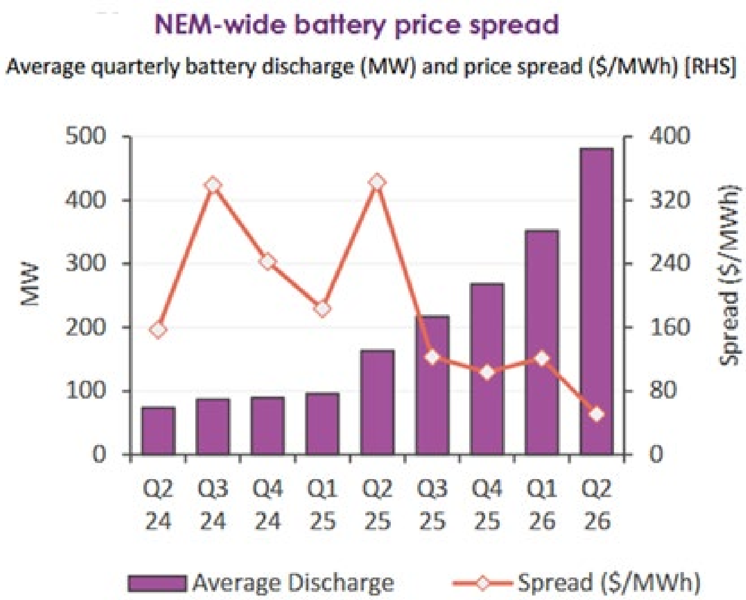
Greater BESS penetration can compress intraday spreads and reduce the marginal value of arbitrage.

In simple terms: many batteries try to buy during the same low-price hours and sell during the same high-price hours. In doing so, they contribute to making the former less cheap and the latter less expensive.

Australia provides particularly clear evidence of this phenomenon.

In New South Wales, the *battery price spread* estimated by AEMO fell from approximately AUD 422/MWh in Q2 2025 to AUD 41/MWh in Q2 2026, a reduction of nearly 90%. Across the NEM as a whole, the indicator declined from approximately AUD 342/MWh to AUD 51/MWh over the same period [14].

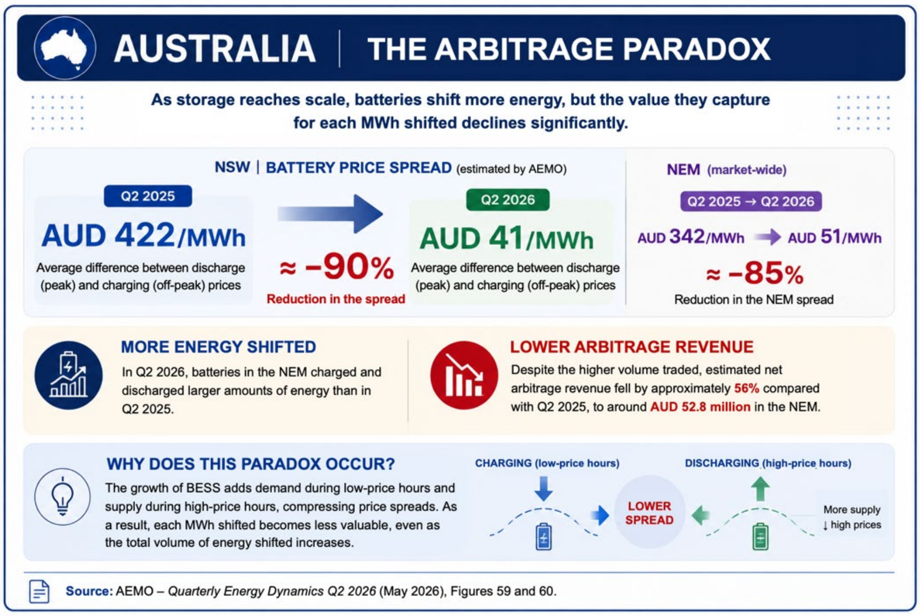
*Figure 5 Evolution of battery discharge and the battery price spread in the NEM*




Source: Australian Energy Market Operator (AEMO), *Quarterly Energy Dynamics Q2 2026*, Figure 59.

The reduction should not be attributed exclusively to the growth of batteries. Price volatility depends on numerous factors, including demand conditions, generation availability, transmission, renewable production, and extraordinary events. However, AEMO identifies the growing participation of energy storage as one of the factors modifying price profiles and arbitrage opportunities.

The result observed in Q2 2026 is particularly illustrative. Although batteries in the NEM charged and discharged greater amounts of energy, their estimated net arbitrage revenues decreased by approximately 56% compared with Q2 2025, to around AUD 52.8 million.




At first glance, this may seem contradictory: batteries operated more, but earned less revenue from arbitrage.

The explanation lies precisely in the evolution of the market. The volume of energy shifted increased, but the value obtained per MWh shifted declined sharply as spreads compressed.

This makes it possible to distinguish between two effects that can occur simultaneously:

- Volume effect: greater capacity, more cycles and more energy shifted can increase total revenues.
- Price effect: smaller differences between charging and discharging prices reduce the value obtained per unit of energy shifted.

The final outcome will depend on which of the two effects predominates.

This dynamic has a direct implication for the economic evaluation of new projects:

> *Historical spreads should not be projected into the future as if they were independent of the amount of energy storage entering the market.*
> *The first battery and a battery entering the market after several additional GW have been deployed may face very different economic conditions.*

## 5.4. Saturation does not occur only in the energy market

The evolution of arbitrage in Australia shows that a source of revenue can lose value as the capacity seeking to take advantage of it increases. However, this phenomenon is not limited to the energy market.

California provides a complementary example through ancillary services.

Batteries have technical characteristics that are particularly well suited to some of these services: they can rapidly adjust their charging or discharging levels and respond within very short timeframes. This made services such as frequency regulation an important source of revenue during the early stages of energy storage development.

However, as installed capacity grew, a shift began to occur.

The California Independent System Operator (CAISO)[4] has observed that BESS capacity grew much more rapidly than the requirements for certain ancillary services. Batteries came to provide a significant share of services such as regulation and reserves, but the size of these markets did not grow at the same pace as the amount of capacity available to provide them [15].

The economic principle is simple:

A limited system need can be met by a limited amount of capacity, regardless of how many additional batteries are available to provide the service.

Once there is sufficient competition to meet that need, new capacity must compete for an opportunity that does not necessarily grow at the same rate.

During 2024, for example, batteries were already providing around 84% of regulation services in the CAISO area. At the same time, the share of their capacity dedicated to certain ancillary services began to decline, while their participation in the energy market increased.

The California case allows us to draw a conclusion that complements the Australian experience:

> *Not only can arbitrage opportunities become saturated; the economic opportunities associated with other services can also progressively decline when the capacity available to provide them grows more rapidly than the system's need for those services.*

This requires careful consideration of the revenue sources used to justify new investments.

## 5.5. From *revenue stacking* to a dynamic value structure

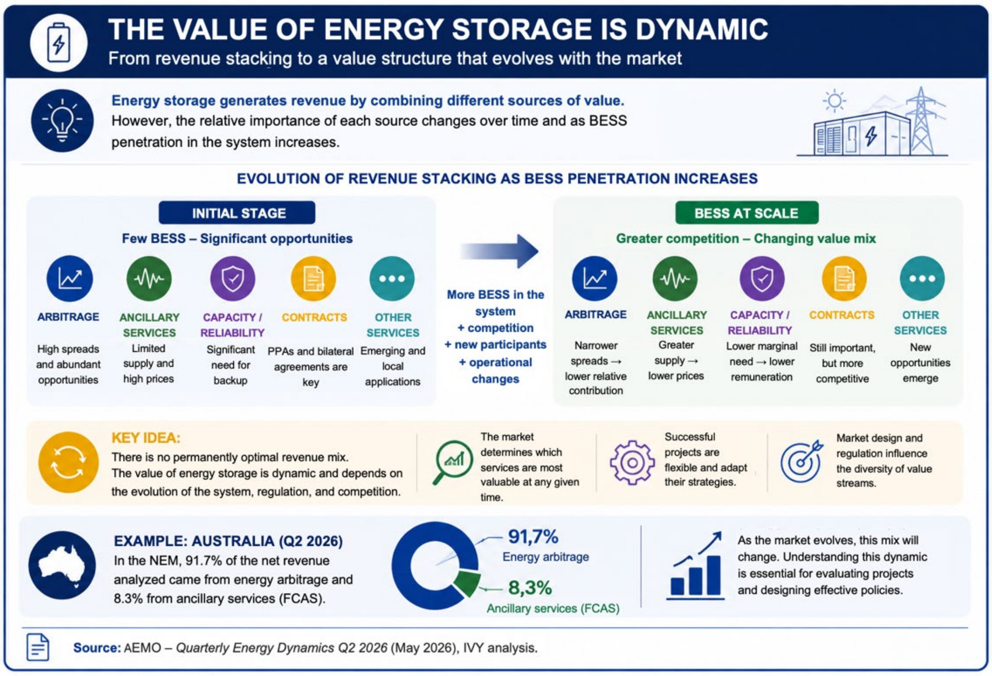
The possibility of participating in different markets has led to the widespread use of the concept of *revenue stacking*: combining different sources of income to support the profitability of an energy storage system.

Depending on the market design, a single battery can earn revenues through energy arbitrage, ancillary services, capacity, contracts, or other mechanisms.

The concept remains valid, but recent experience shows that it must be interpreted dynamically.

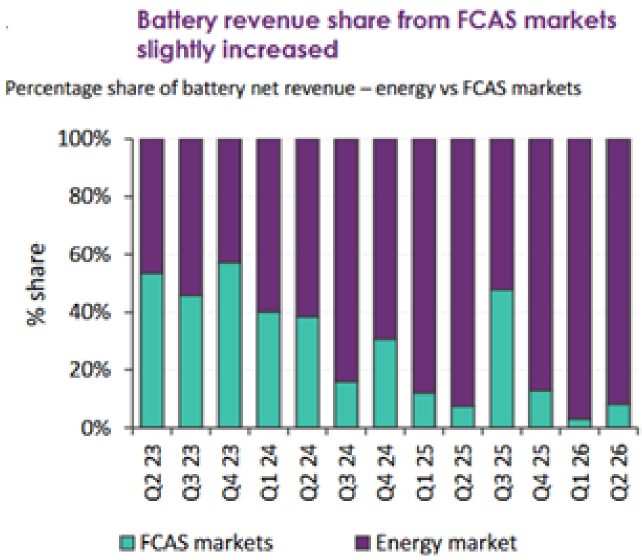
> *The different revenue streams do not necessarily remain constant as energy storage penetration increases.*

[4] California Independent System Operator (CAISO): independent system operator responsible for managing the operation of most of California's power system and administering its wholesale electricity market, coordinating generation dispatch, transmission network operations, and the energy and ancillary services markets.




The Australian experience shows how this revenue structure can evolve as energy storage penetration increases. As the NEM case demonstrates, the relative importance of energy arbitrage and ancillary services has changed significantly with the expansion of BESS and the evolution of market conditions [14].

*Figure 6 Evolution of the composition of battery revenues in the NEM: energy market and FCAS*




Source: Australian Energy Market Operator (AEMO), *Quarterly Energy Dynamics Q2 2026*, Figure 58: "Battery revenue from FCAS markets dropped."

Although the relative share of FCAS increased slightly compared with Q2 2025, this was not due to growth in those revenues. On the contrary, FCAS revenues declined by 51% year-on-year, to AUD 4.8 million, while net energy arbitrage revenues fell even more sharply, by 56%, to AUD 52.8 million, as a result of the strong compression of intraday price spreads [14].

The result illustrates that the composition of revenues can change not only because one source of value increases, but also because others lose importance more rapidly.

The diversification of revenue streams can also be complemented by the geographic diversification of assets. Arbitrage opportunities do not necessarily arise simultaneously across different power systems, as they respond to different combinations of renewable generation, demand, weather conditions, and interconnections. A recent analysis of European markets shows, for example, a low degree of temporal overlap between the days with the highest *spreads* in Spain and those observed in other markets, which can help diversify the risk of energy storage portfolios exposed to different systems [1].

This dimension is particularly relevant for investors developing energy storage portfolios across different markets: what matters is not only the expected value of each asset, but also the degree of correlation between their revenue opportunities.

Nor should energy arbitrage be interpreted as permanently replacing ancillary services as the main source of revenue. The relative importance of each market may change over time and, as the Australian experience shows, both arbitrage revenues and revenues associated with FCAS may decline as system conditions evolve and BESS participation increases.

In particular, energy arbitrage can experience a significant compression of spreads when energy storage reaches sufficient scale and begins to modify the very price differentials that initially made this service attractive.

The economic model of energy storage is, therefore, *evolutionary*.

One source of value may be particularly attractive during the early stages of development; the entry of new capacity increases competition; the marginal value of that service may decline; and assets begin to seek other opportunities within the system.

This makes it possible to move from a static interpretation of *revenue stacking* toward a broader concept:

> *The economic viability of energy storage depends not only on how many revenue streams an asset can combine, but also on how the value of those streams evolves as the system changes and the penetration of energy storage itself increases.*

Consequently, risk diversification can occur along two dimensions: by combining different revenue streams within a single asset (revenue stacking) and, for investors with project portfolios, through assets exposed to markets whose value patterns do not necessarily coincide over time.

These considerations are particularly relevant for countries in Latin America and the Caribbean that are beginning to design mechanisms to integrate energy storage. Replicating the revenues currently observed in more mature markets may lead to misleading conclusions if it is not taken into account that those same markets are evolving as a result of the large-scale deployment of batteries.

### 5.6. From asset value to system needs

Australia and California illustrate two manifestations of the same phenomenon.

In Australia, the growth of energy storage is contributing to changes in price profiles and to a reduction in certain arbitrage opportunities [14]. In California, the expansion of BESS has increased competition in ancillary services that initially represented an important source of value [15].

In both cases, the conclusion is similar:

> *The economic signals that incentivize the first investments in energy storage do not necessarily remain unchanged as installed capacity increases significantly.*

This does not mean that energy storage loses value to the system. On the contrary, part of the reduction in certain economic opportunities may be precisely the result of batteries effectively fulfilling their function: reducing price differentials, providing fast-response services, or increasing available flexibility.

But it does mean that system value, private revenue, and investment signals must be analyzed as related but distinct concepts.

> *This realization changes the question that planning must ask. Instead of starting by asking how many MW of batteries should be deployed, it is necessary to identify what flexibility needs the system has, for how long, in which locations, and which resources can meet them efficiently.*

## 6. Energy storage and flexibility: the decisions facing Latin America and the Caribbean

The previous chapters showed how, in markets where batteries have reached a significant level of participation, energy storage begins to modify not only power system operations, but also price profiles and the very sources of value that support its development. The experiences of Australia and California make it possible to observe phenomena that are likely to become increasingly relevant as other power systems move forward with the incorporation of energy storage.

> *For Latin America and the Caribbean, however, the main lesson is not to replicate the solutions adopted in those markets, but rather to use their experience to better inform the decisions that the region will need to make.*

Power systems in Latin America and the Caribbean have highly diverse characteristics. Some have a high share of hydropower and, therefore, resources that already provide significant flexibility; others are experiencing rapid growth in solar and wind generation; some face transmission constraints that limit the utilization of their renewable resources; and numerous island systems in the Caribbean operate at a smaller scale, with limited interconnection and a strong dependence on imported fuels. Consequently, the same energy storage solution can have very different values depending on the system in which it is incorporated.

Therefore, planning should not begin by asking how many MW of batteries a country needs. The question should be framed differently:

> *What flexibility needs will the system have, where and when will they arise, for how long will they need to be met, and what combination of resources can meet them most efficiently?*

This shift in perspective makes it possible to move from considering energy storage as an objective in itself to understanding it as one of the possible responses to the flexibility needs of the power system.

## 6.1. Energy storage is not an objective in itself

The rapid decline in battery costs, their growing deployment worldwide, and their ability to provide multiple services have turned energy storage into one of the most visible components of the energy transition. This has led several countries to establish energy storage capacity targets or explicitly incorporate this technology into their expansion plans.

These targets can be useful for guiding policy and providing signals to the market. However, installed energy storage capacity should not, by itself, become a measure of progress in the energy transition.

From the perspective of the power system, a battery has value to the extent that it helps address a specific need: shifting energy between periods, providing reserves, responding rapidly to imbalances, reducing renewable energy curtailment, alleviating certain network congestion, or helping meet periods of high net demand, among other services.

This is particularly relevant for Latin America and the Caribbean because needs differ across countries and even across different areas within the same power system.

In a system with abundant reservoir hydropower, for example, part of the required flexibility may already be available from existing resources. In an island system dependent on imported fuels for thermal generation, a battery combined with solar generation can reduce fuel consumption and improve system operations. In another system, with large renewable resources located far from demand centers, the main constraint may lie in transmission rather than necessarily in a general lack of energy storage.

Therefore:

> *The challenge is not to determine how much energy storage can be installed, but rather which system problems it can solve efficiently.*

This distinction may seem simple, but it has important implications for planning. Two systems with the same share of solar generation may require completely different amounts and characteristics of energy storage if one has flexible hydropower generation and strong interconnections, while the other operates in isolation and with inflexible thermal generation.

## 6.2. What does flexibility mean in a power system?

In technical terms, flexibility is the ability of the power system to respond to expected or unexpected variations in supply and demand, while maintaining at all times the balance required for safe and reliable operation.

In more intuitive terms, a flexible system is one that can adapt when conditions change.

This capability has always been necessary. Electricity demand has never been constant, and power systems have had to continuously adjust generation to follow its variations. The expansion of wind and solar generation introduces an additional dimension: a growing share of supply depends on resources whose output varies with weather conditions and cannot be dispatched in the same way as a conventional power plant.

The need for flexibility also occurs across different timescales:

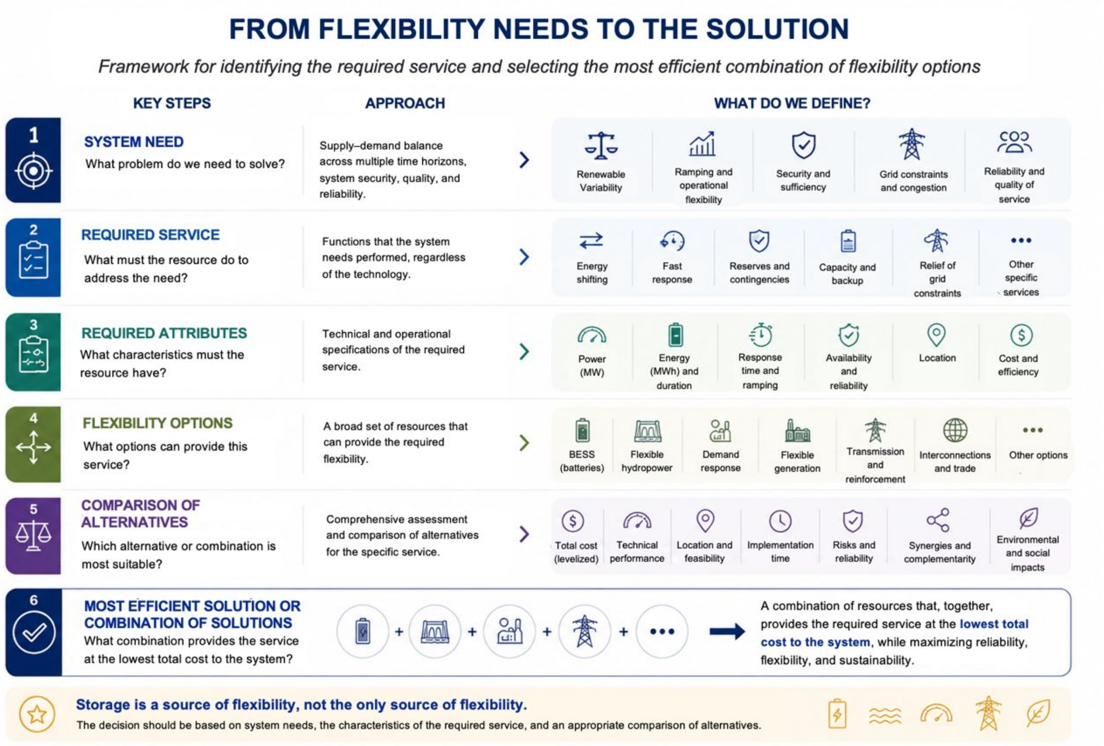
- In seconds or minutes, the system needs resources capable of responding rapidly to frequency deviations or unexpected changes.
- Over periods ranging from minutes to hours, it may be necessary to follow ramps in demand or renewable generation, provide reserves, and manage intraday variations.
- Over periods of several hours, the challenge may involve shifting large amounts of energy from times of abundance to periods of higher net demand.
- And in some systems, there may be longer-duration needs associated, for example, with prolonged periods of low renewable generation, adverse hydrological conditions, or contingencies.

Not all of these needs are the same and, therefore, they do not necessarily require the same technological solution.

This distinction is particularly important when analyzing BESS. Lithium-ion batteries offer a particularly attractive combination of response speed, modularity, and the ability to shift energy during certain hours. However, a technology that is highly efficient at providing rapid response or shifting energy from midday to the evening is not necessarily the lowest-cost solution for covering deficits that extend over several days.

> *Planning should therefore first identify the nature and duration of the flexibility need, and only then determine which resource can meet it.*

*Figure 7 Technological solutions according to flexibility needs*




## 6.3. Not all flexibility needs require energy storage

Energy storage is a source of flexibility, but it is not the only one. A power system can obtain flexibility through dispatchable hydropower generation, thermal power plants capable of rapidly adjusting their output, demand response, interconnections with other systems, electric vehicle management, network expansion, pumped-storage hydropower, and different energy storage technologies, among other alternatives.

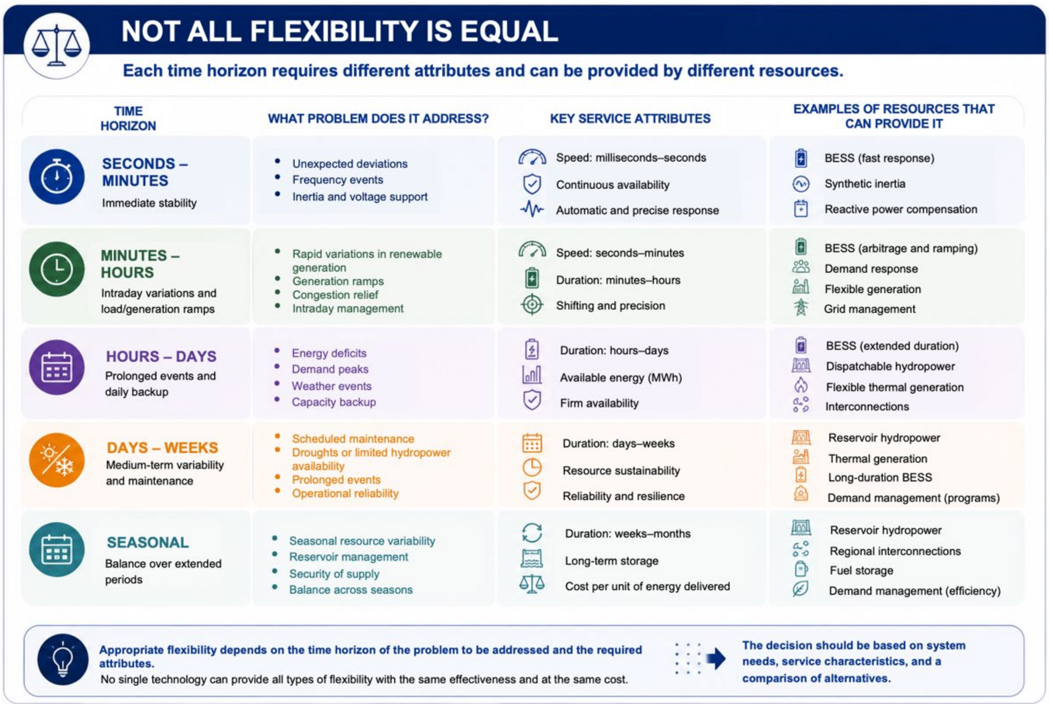
In many cases, these options are not perfect substitutes. They can complement one another and provide different services.

This consideration is particularly relevant in Latin America and the Caribbean due to the significant share of hydropower in several power systems across the region. Under certain conditions, a hydropower reservoir is an extremely valuable source of flexibility because it allows for adjusting when stored water is used to generate electricity.

This does not mean that a predominantly hydropower-based system does not need batteries. Their technical characteristics are different. A battery can respond extremely quickly, provide certain network services, and operate locally; a reservoir can store large amounts of energy over much longer periods. The two resources can be complementary.

Something similar occurs with transmission. If one region has renewable energy surpluses while another needs energy, transmission expansion can make it possible to take advantage of this complementarity. Installing energy storage at the point of generation may be another alternative. The efficient decision will depend on costs, network constraints, hourly generation and demand profiles, and the other services that each investment can provide.

*Figure 8  Not all flexibility is equivalent*




Demand response introduces a third possibility. Certain types of consumption can be shifted to hours of greater renewable energy availability, reducing the need to store electricity for later use.

In physical terms, there are therefore two ways to address a temporal mismatch between production and consumption: shifting energy to the time when it is needed, or shifting part of consumption to the time when energy is available.

This latter alternative may become increasingly important with the electrification of transport, heating and cooling systems, certain industrial processes, and other loads that can incorporate some degree of temporal management.

The conclusion is not that one alternative is superior to another. It is precisely the opposite:

> *Flexibility is a system need; energy storage is one of the technologies that can provide it.*
> *Planning should allow different resources to compete or complement one another in meeting that need as efficiently as possible.*

## 6.4. Power, energy and duration: key dimensions of energy storage

One of the difficulties when discussing energy storage is that its size is often expressed only in MW. However, a battery's power capacity alone does not indicate how long it can provide that level of power.

Power, expressed in MW, indicates the maximum rate at which the system can charge or discharge energy. Energy capacity, expressed in MWh, indicates how much energy it can store.

The relationship between the two provides a simple measure of duration.

A 100 MW / 100 MWh battery could, in simplified terms, deliver its rated power for approximately one hour.

A 100 MW / 400 MWh battery could do so for approximately four hours.

Both have 100 MW of power capacity, but their ability to meet system needs is very different.

This concept becomes particularly important as renewable energy penetration increases. In the early stages, a short-duration battery can provide significant value through frequency regulation, reserves, or response to rapid variations. As solar generation increases, the ability to shift energy over several hours, from periods of high solar generation to the evening peak, may become increasingly important.

And if the challenge extends over even longer periods, the economic and technological characteristics change once again.

For this reason, a target expressed exclusively as “X MW of energy storage” provides incomplete information. To understand what that capacity can actually contribute, it is also necessary to know the associated MWh and, therefore, its duration.

But even MW and MWh may be insufficient.

Response speed, cycle efficiency, the expected number of cycles[5], degradation, availability, and the conditions under which the resource will be required to operate also matter. The needs of the system should define the characteristics of the resource, not the other way around.

## 6.5. Location also creates value

The value of energy storage depends not only on its power and duration. It also depends on where it is connected.

This dimension is particularly important in power systems where the development of renewable generation is advancing more rapidly than transmission expansion.

Chile provides a particularly relevant example for Latin America. The strong expansion of solar generation in the north of the country has coincided with transmission constraints and periods of high renewable energy curtailment. Under these conditions, installing energy storage near areas with surplus

[5] **Battery cycle:** the process of charging and subsequently discharging the stored energy. In practice, cycles may be full or partial, depending on the proportion of the battery’s capacity used in each operation. The frequency and depth of these cycles affect the degradation and useful life of the system.

generation can make it possible to capture some of the energy that would otherwise be unavailable for use at that time and shift it to hours of higher value.

But this example also shows why energy storage and transmission should not be analyzed in isolation.

A battery can shift energy over time. A transmission line can shift it across space.

When there is a network constraint, both investments can address different dimensions of the problem. In some cases, they may partially substitute for one another; in others, they will clearly be complementary.

This distinction has economic implications. Two technically identical batteries, with the same power and energy capacity, can provide very different value to the system depending on the node where they are located, existing constraints, and the behavior of local generation and demand.

Location takes on yet another dimension in island systems in the Caribbean. There, a battery can contribute not only to integrating renewable generation, but also to reducing the operation of high-cost thermal units, providing reserves, responding rapidly to contingencies, and reducing dependence on imported fuels.

The value of energy storage is therefore temporal, technological, and spatial.

> *This characteristic poses a challenge for investment mechanisms. A uniform economic signal across the entire system may not adequately reflect the fact that certain resources have much greater value when located at specific points on the network.*

## 6.6. From capacity targets to service needs

National energy storage targets can play a useful role. They can increase the visibility of an emerging technology, mobilize investment, and signal that planning recognizes the growing need for flexibility.

However, as power systems evolve, capacity targets should be complemented by an increasingly precise identification of the services the system needs.

Rather than limiting the analysis to a question such as: How many MW of energy storage do we need?

Planning should progressively address a more comprehensive set of questions:

What service do we need? Where? When? With what response speed? For how long? How often? And which resources can provide it at the lowest cost to the system?

This approach may lead to different answers across countries in Latin America and the Caribbean.

A system with high solar penetration may primarily require capacity to shift energy over several hours. Another may need rapid response and reserves. A hydropower-based system may already have significant flexibility resources but face local network constraints. An island system may place particular value on the ability to reduce imported fuel consumption while simultaneously providing stability services.

Therefore, there is no optimal amount of energy storage that can be determined based on renewable energy penetration alone.

The need depends on the existing generation mix, the shape of demand, network characteristics, interconnections, available flexibility resources, hydrological conditions, the expected evolution of electrification, and the levels of reliability that each system aims to maintain.

This has a particularly important implication for the region. As the penetration of variable renewable energy increases, expansion studies will need to represent the system's operational needs in greater detail. A model that determines only how much energy must be produced over the course of a year may be insufficient to identify needs that arise during specific hours, in particular areas of the network, or in response to rapid ramps in generation and demand.

> *Planning for flexibility requires increasingly linking expansion decisions to how the system will have to operate.*

This shift does not eliminate the need to establish policies to promote energy storage. On the contrary, it makes it possible to design them more effectively. Once the system's needs have been identified, it is possible to determine which barriers prevent investments from responding to those needs and which economic or regulatory signals are necessary to enable the development of resources capable of providing those services.

> *The appropriate sequence would therefore be:*
> *system need → required service → technical characteristics → available alternatives → economic signal → investment*
> *Not the other way around.*

## 6.7. From system needs to investment signals

The analysis developed in this chapter leads to an important conclusion for Latin America and the Caribbean. Incorporating energy storage should not be an isolated objective of energy planning. The objective is to ensure sufficient flexibility to operate increasingly renewable, electrified, and complex power systems while maintaining adequate levels of security, efficiency, and reliability.

Batteries will play an increasingly important role in this transformation, but their contribution will depend on the characteristics of each system and the specific needs they are intended to address.

This raises a new question. Even when planning correctly identifies where, when, and what type of flexibility the system needs, are there economic signals that allow an investment capable of providing that flexibility to adequately recover its value?

The previous chapters showed that system value and private revenue do not necessarily coincide. They also showed that revenue streams can evolve and become saturated as energy storage penetration increases.

The next challenge, therefore, is to translate the system's needs into signals that guide efficient investment and operational decisions.

# 7. Implications for power system planning, regulation and electricity market design in Latin America and the Caribbean

The previous chapter argued that the incorporation of energy storage should be driven by the system's flexibility needs rather than by technological targets considered in isolation. Identifying those needs, however, is only part of the challenge. Once it has been determined what service the system requires, where it must be provided, and for how long, it is necessary to create the conditions for investments capable of providing it to actually materialize.

Here, a fundamental distinction emerges that was introduced earlier: the value that a resource provides to the system does not necessarily coincide with the revenues its owner can capture.

A battery can reduce renewable energy curtailment, provide reserves, alleviate certain network constraints, shift energy to periods of higher demand, or avoid the use of more costly resources. All of these benefits can represent value to the system. However, if the regulatory and market design does not allow them to be adequately remunerated, that value does not necessarily translate into a sufficient signal to justify the investment.

The problem can be stated simply:

> *Identifying that the system needs flexibility does not guarantee that there is an economic signal capable of mobilizing the investment needed to provide it.*

This issue is particularly relevant for Latin America and the Caribbean. The region includes power systems with very different institutional structures and market designs: organized wholesale markets, systems with long-term contracting, vertically integrated utilities, and small island systems, among other configurations. Consequently, the signals needed to support the development of energy storage do not necessarily have to be the same across all countries.

## 7.1. The investment signal problem

Operational decisions and investment decisions respond to different time horizons.

In daily operations, prices can indicate that energy is abundant during certain hours and scarce during others. A battery can respond to these signals by charging when prices are low and discharging when they are high.

But deciding to build a battery is a different decision.

The investor must commit capital today with the expectation of recovering that investment over several years. To do so, the investor needs to assess not only the revenues the asset could earn today, but also how those revenues may evolve in the future, the associated risks, and the stability of the rules under which it will operate.

> *An adequate signal for operations does not necessarily constitute a sufficient signal for investment.*

This difference is particularly important for energy storage because, as Chapter 5 showed, some of its revenue sources can change precisely as a result of new capacity entering the market. The *spreads* used for arbitrage can compress, and certain ancillary services markets can become saturated.

There is, therefore, an important tension: the system may need greater flexibility in the future, while current market revenues alone may not provide sufficient certainty to finance the assets that will be needed to provide it.

This situation does not necessarily imply a market failure, nor does it automatically lead to the need for subsidies. It does, however, indicate that the adequacy of investment signals must be explicitly assessed, taking into account the characteristics of the system, its market design, and the services that energy storage is expected to provide.

## 7.2. Where do energy storage revenues come from?

As discussed in Chapter 5, energy storage can generate revenues from different sources, including energy arbitrage, ancillary services, capacity, adequacy, or reliability mechanisms, long-term contracts, and, where the regulatory framework allows, certain network-related services.

The possibility of combining several of these sources explains the importance of *revenue stacking* for the economic viability of projects. However, from an investment perspective, it is not enough to identify how many revenue streams are available or their value under current market conditions.

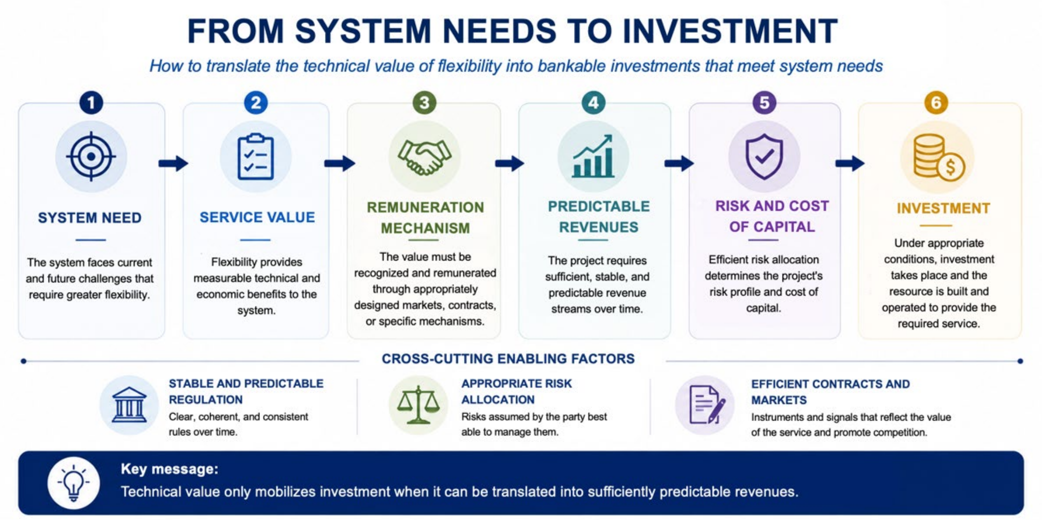
The experience analyzed shows that these revenues can evolve over the useful life of the asset. The spreads that support arbitrage may compress as energy storage capacity increases, while certain ancillary services markets may experience increasing competition. At the same time, other sources of value may become more relevant as the system's needs change.

Therefore, the economic evaluation of an energy storage project should consider not only the revenues it can earn at the time of investment, but also their predictability, the possibility of combining them, and their expected evolution over the useful life of the asset.

This last consideration leads to an additional question:

> *The existence of revenue streams does not, by itself, guarantee that a project is financeable. The stability of those revenues and the risks associated with*

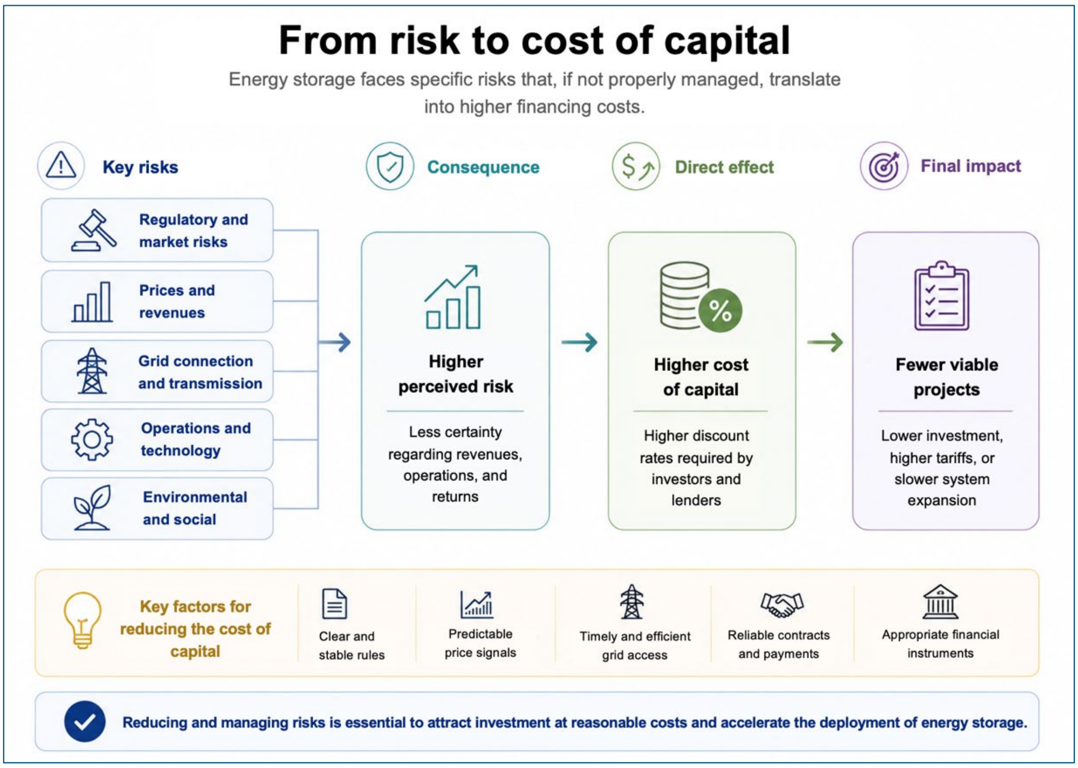
*obtaining them will be critical to transforming the economic value of energy storage into a viable investment*.




## 7.3. Bankability and cost of capital: beyond market design

The existence of different revenue streams does not necessarily mean that an investment is easily financeable. For those providing capital or financing, what matters is not only how much a project can earn, but also the level of risk associated with those revenues and with the environment in which the investment must be recovered.

Here, it is useful to introduce the concept of bankability: a project's ability to access financing under conditions that enable its development, taking into account the predictability of its revenues, the allocation of risks, contractual soundness, the quality of counterparties, and the institutional and economic environment in which the investment is made.




This dimension is particularly important for Latin America and the Caribbean. The cost of financing an energy project does not depend exclusively on its technical characteristics or on the specific rules of the electricity market. A significant part of the cost of capital is determined by factors that extend beyond the energy sector, such as country risk, macroeconomic stability, institutional quality, legal certainty, regulatory stability, the independence and functioning of institutions, and, more generally, the perceived risk associated with investing in each country.

As a result, two technically similar projects, with comparable equipment costs and capable of providing the same services to the system, may face very different financing costs depending on the country in which they are developed.

This difference is particularly relevant for capital-intensive technologies, such as renewable energy and energy storage. Once the initial investment has been made, their variable operating costs are relatively low. Therefore, the cost of capital can become one of the main determinants of the final cost of the service they provide.

This introduces an important consideration for regional energy policy. The global decline in battery prices does not necessarily translate into the same reduction in the cost of energy storage across all countries. Part of this technological advantage may be offset, or even substantially outweighed, by higher financing costs.

Some of these risks can be reduced within the energy sector itself. A stable regulatory framework, clear contracts, creditworthy counterparties, transparent procedures, appropriate risk-allocation mechanisms, and predictable rules can improve project bankability and reduce financing costs.

But other factors lie beyond the scope of energy policy.

Sectoral regulation can reduce certain project risks, but it cannot eliminate the risk associated with the economic and institutional environment of the country in which the investment is made.

This distinction is important because it avoids attributing to electricity market design a capability that it does not have. Even a technically well-designed remuneration mechanism may face high capital costs if investors perceive significant risks related to macroeconomic stability, institutional quality, or legal certainty.

In these cases, instruments capable of reducing or reallocating certain risks may become particularly important, such as guarantees, concessional financing, participation by multilateral development banks, blended finance[6] structures, or other risk-mitigation mechanisms. Their role should not be to hide economically inefficient projects, but rather to help reduce those risk premiums that make it difficult for investments that are efficient for the system to obtain financing under reasonable conditions.

Therefore, when analyzing the signals needed to develop energy storage in Latin America and the Caribbean, it is necessary to consider two dimensions simultaneously:

the economic signal that determines the revenues the project can earn, and the cost of capital at which those revenues can be converted into a financeable investment.

A project may have the former and still fail because of the latter.

Consequently:

> *The bankability of energy storage depends not only on creating new revenue sources, but also on appropriately reducing, allocating, and managing the risks that determine its cost of capital.*

## 7.4. Short-term signals and long-term decisions

Electricity markets must simultaneously address two different problems.

- The first is operational: deciding which resources should produce, consume, charge, or discharge at any given time in order to maintain system balance efficiently.
- The second concerns investment: ensuring that sufficient capacity and flexibility are available in the future so that the system can continue to operate safely and efficiently.

[6] **Blended finance:** a mechanism that combines public, concessional or development agency resources with private capital, using instruments such as guarantees, subordinated financing or other forms of risk mitigation to improve the financial conditions of projects and facilitate the mobilization of private investment.

Short-term prices are fundamental to addressing the first problem. When they adequately reflect system conditions, they provide signals for batteries to charge, discharge, or reserve capacity to provide certain services.

However, investments are recovered over much longer time horizons than those over which these prices are formed.

This time difference raises a central question for market design:

How can short-term economic signals, which are necessarily variable, be translated into revenue expectations that are sufficiently robust to sustain long-term investment decisions?

There is no single answer.

In some markets, a significant share of the risk may remain with the investor, who develops the project relying on future revenues from energy and ancillary services. In others, long-term contracts, capacity mechanisms, or other instruments may provide greater revenue stability.

The choice also involves an allocation of risks.

The greater the protection provided to the investor against market volatility, the greater the share of risk that will normally have to be assumed by another counterparty: a buyer, consumers, an electric utility, or some entity defined by the regulatory framework.

> *Therefore, reducing risk does not mean eliminating it; it means deciding who is best positioned to assume and manage it.*

This consideration is fundamental when designing mechanisms for energy storage. Providing too much protection may weaken incentives to respond efficiently to system signals. Providing too little protection may prevent necessary projects from obtaining financing or significantly increase their cost of capital.

The objective is to find a balance between certainty for investment and sufficient exposure to signals that incentivize efficient operation.

## 7.5. Contracts, markets, and remuneration mechanisms

International experience shows different ways of addressing this balance. Not all of them address the same problem, nor are they necessarily transferable across power systems.

Energy and ancillary services markets allow resources to be remunerated when they effectively provide operational value. Their strength is that they can generate dynamic signals and allow different technologies to compete to provide specific services.

Long-term contracts can provide predictability and facilitate financing, particularly when purely market-based revenues are highly uncertain.

Capacity or reliability mechanisms, when they exist, can recognize the contribution of certain resources to system sufficiency, provided that their rules adequately reflect the effective ability of energy storage to respond during critical conditions.

Specific mechanisms can also be designed to address localized needs, for example, when a network constraint or a particular flexibility need has been identified through planning.

> *The regulatory question should not simply be: What incentive does a battery need?*
>
> *A more appropriate formulation would be:*
> *What service does the system need, how should it be valued, and what mechanism allows it to be procured or remunerated efficiently?*

This distinction is important because it maintains a certain degree of technological neutrality[7].

If the system needs rapid response, capacity for four hours, or flexibility at a specific point in the network, the design should seek to express that need through verifiable service characteristics. Where possible, different technologies should be able to compete to provide it.

This does not mean ignoring the specific characteristics of energy storage. There are specific regulatory barriers that may prevent its efficient participation, for example, rules designed around the traditional separation between generation and demand that need to be corrected.

But there is a difference between removing barriers so that energy storage can compete and designing the market specifically around a particular technology.

## 7.6. What does this mean for Latin America and the Caribbean?

The diversity of Latin America and the Caribbean makes it inadvisable to seek a single regional model for remunerating energy storage.

In systems with well-developed spot markets and high renewable energy penetration, improving temporal and spatial price signals can allow a significant share of the value of energy storage to be recognized directly by the market.

In systems where long-term contracting plays a central role in expansion, it may be necessary to consider how to incorporate attributes such as flexibility, availability, or the ability to shift energy over time into those contracts.

In vertically integrated systems, the question may be different: how to adequately compare energy storage with alternative investments in generation, networks, or

[7] **Technological neutrality:** a principle under which rules or mechanisms seek to define the required service or outcome, allowing different technologies capable of meeting the established requirements to compete to provide it, unless there are technical reasons that justify specific treatment.

demand-side management within the planning process, while recognizing all costs and benefits over their useful life.

In small island systems in the Caribbean, energy storage can compete directly with thermal generation fueled by imported fuels while simultaneously providing multiple operational services. In these systems, the economic analysis may need to consider not only arbitrage, but also fuel savings, reserves, reduced renewable energy curtailment, and potential avoided investments.

These differences reinforce a central conclusion:

> *The region does not necessarily need a single model to promote energy storage; it needs frameworks capable of recognizing and remunerating the different forms of flexibility required by each system.*

This implies at least three conditions.

- First, planning must identify needs sufficiently in advance. An economic signal is unlikely to induce investment if the system has not previously identified what service it will need, where, and when.
- Second, the rules must allow resources capable of providing these services to participate and be remunerated. Energy storage should not be excluded simply because certain rules were designed for a system in which generation and consumption were completely separate categories.
- Third, signals must be compatible with investment horizons. When short-term revenues do not provide sufficient predictability to mobilize investments that the system has identified as efficient, it may be necessary to consider mechanisms that reduce certain risks without eliminating incentives for efficient operation.

> *The ultimate objective should not be to maximize installed battery capacity. The objective should be for investment decisions to respond to the system's actual flexibility needs and for resources capable of providing that flexibility to receive economic signals consistent with the value they provide.*

## 7.7. From investment signals to an agenda for the region

The review and identification of lessons learned from power systems with a high share of BESS, together with the analysis of their current and future impacts, leads us to two basic energy policy questions: what flexibility does each system need, and what signals will enable the investments capable of providing it to emerge?

For Latin America and the Caribbean, this suggests that the next stage of energy storage development should not focus solely on establishing capacity targets or incorporating batteries into expansion plans. It requires simultaneous progress in planning, regulation, market design, and procurement mechanisms.

The sequence presented at the end of the previous chapter can now be completed:

> *system need → required service → technical characteristics → available alternatives → service valuation → economic signal → efficient investment and operation.*

Energy storage will play an increasingly important role within this sequence, but its sustainable development will depend less on creating incentives for a specific technology and more on building systems capable of recognizing, valuing, and remunerating the flexibility they need.

# 8. An agenda for Latin America and the Caribbean

The analysis developed throughout this Note shows that energy storage is entering a new stage. Its rapid expansion, particularly through battery energy storage systems, is not only increasing the ability of power systems to integrate renewable generation and respond to variations in supply and demand. In markets where it has reached a significant scale, it is also beginning to modify system operations, price profiles, and the very economic conditions that determine its value.

These experiences offer important lessons for Latin America and the Caribbean, but they do not constitute models that should be mechanically replicated. The diversity of the region's power systems in terms of available resources, hydropower share, renewable energy penetration, network characteristics, degree of interconnection, institutional structure, and market design means that energy storage and flexibility needs will necessarily differ.

> *Therefore, the next stage of energy storage development in Latin America and the Caribbean should move from a discussion focused primarily on how much capacity to install toward a broader one: what flexibility each system needs, where and when it needs it, which resources can provide it, and what signals will enable the necessary investments to be mobilized.*

From this perspective, several elements for a regional agenda can be identified.

## 8.1. Start with system needs, not technology

The first decision is also the most important: energy storage should not be an objective in itself.

Capacity targets can be useful for providing visibility, guiding policy, and mobilizing investment. However, they do not replace the analysis of the needs that the system must address.

Planning should begin by identifying flexibility requirements: rapid response, reserves, shifting energy between hours, capacity during critical periods, reducing curtailment, alleviating network constraints, or other services. Based on these needs, the attributes that the resource must provide should be defined: power, available energy, duration, response speed, location, availability, or other relevant characteristics.

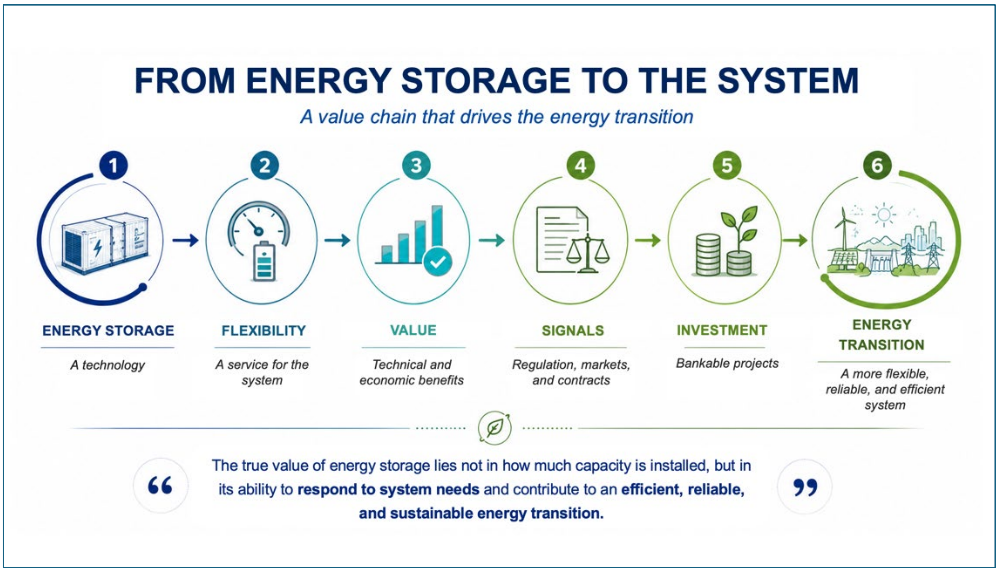
Only then should it be assessed which technologies or combinations of resources can provide those attributes efficiently. This approach avoids an overly simplified question: How many MW of batteries does the system need?

And replaces it with a more comprehensive one: What service does the system need? Where, when, and for how long must it be provided? What attributes does it require, and which alternatives can provide it most efficiently?

In some cases, the answer will be BESS. In others, it may be flexible hydropower generation, demand response, transmission, interconnections, pumped-storage hydropower, or other technologies. In many cases, the most efficient solution will be a combination of resources.

This perspective is particularly relevant for Latin America and the Caribbean, where power systems with similar levels of renewable energy penetration may have very different flexibility capabilities and needs. The need for energy storage cannot be determined solely by how much wind or solar generation a system has; it also depends on the other resources available to manage its variability.

> *Defining needs and attributes, rather than predetermining technologies, also allows solutions to evolve alongside the system and prevents decisions made today from unnecessarily limiting future technological options*.




## 8.2. Properly incorporating flexibility into planning

Correctly identifying these needs also requires planning tools to evolve.

As the share of wind and solar generation increases, it becomes increasingly insufficient to know only how much energy the system can produce over the course of a year. It is also important to determine when that energy is available and whether there are resources capable of shifting, complementing, or replacing it when operating conditions change.

This requires representing, in sufficient detail, hourly and, where appropriate, sub-hourly generation profiles (capturing renewable variability with sufficient granularity) and demand profiles, ramps, transmission constraints, curtailment, reserve requirements, and the complementarity among different flexible resources.

In the case of energy storage, characteristics such as power, energy capacity, duration, efficiency, degradation, and operating constraints must also be adequately represented. As discussed earlier, expressing a need solely in MW may be insufficient: the amount of energy available and the length of time over which it can be delivered are equally important.

This need takes on particular characteristics in Latin America and the Caribbean. The high share of hydropower in several of the region's power systems can provide an important source of flexibility and complementarity with wind and solar generation. In other cases, particularly in island systems, energy storage can simultaneously contribute to integrating renewables, reducing imported fuel consumption, and providing operational services.

In addition, generation, energy storage, and transmission planning should not be carried out in isolation. As noted in Chapter 6, energy storage can shift energy over time, while transmission can shift it across space. In some cases, they will be partial alternatives; in others, clearly complementary investments.

> *Therefore: Planning energy storage requires planning the system in which it will operate.*

## 8.3. Recognizing and remunerating services, not just assets

Once the system's needs have been identified, the regulatory and market framework must allow resources capable of meeting them to participate and receive remuneration consistent with the services they provide.

This is particularly relevant for energy storage because a battery can act as demand when charging and as supply when discharging, while also providing ancillary services, capacity, or other services depending on the design of each system. Rules designed for systems in which generation and consumption were clearly separate categories may create barriers or inappropriate treatment when applied to energy storage.

The response, however, should not necessarily consist of creating mechanisms exclusively for batteries. Where technically feasible, regulation should define the service the system needs and allow different resources capable of providing it to compete to do so.

This means removing unjustified barriers to energy storage and adequately recognizing the services it provides, while at the same time preserving a reasonable degree of technological neutrality.

The distinction is important: facilitating the participation of energy storage does not mean predetermining that energy storage should always be the solution.

> *The regulatory challenge, therefore, is to establish mechanisms that make it possible to value and remunerate the services the system actually needs, avoiding reliance exclusively on a single revenue source or a specific application of energy storage.*

This approach also makes it possible to prepare power systems for technological developments that are difficult to anticipate. If regulation remunerates attributes and services - such as response, availability, duration, location, or energy-shifting capability - rather than specific technologies, it can facilitate competition between the solutions available today and those that may be developed in the future.

## 8.4. Recognizing that value depends on when and where the service is provided

The previous chapters showed that the value of energy storage has a temporal dimension. The same amount of energy can have very different values depending on when it is available.

But value also has a spatial dimension. A battery located in an area with frequent renewable energy surpluses and transmission constraints may provide different value from a technically identical asset connected elsewhere in the system. Similarly, a localized flexibility need cannot necessarily be addressed by capacity installed at any point in the network.

Therefore, economic signals should reflect, to the extent permitted by the design of each system, both when and where flexibility provides value.

This does not necessarily imply adopting a particular pricing or market model. The region's power systems have structures that are too different for that. It does, however, imply recognizing a general principle: overly uniform signals may obscure important differences in the value provided by a resource depending on where and when it operates.

This consideration will become increasingly relevant as renewable generation development becomes concentrated in areas with exceptional resources but located far from major demand centers, or when transmission expansion progresses at a different pace from new generation.

The Chilean case, analyzed earlier, clearly illustrates this dimension.

> *The coexistence of abundant renewable resources, transmission constraints, and periods of curtailment creates opportunities for energy storage to provide value by shifting energy over time. But it also demonstrates that energy storage and network expansion must be evaluated in a coordinated manner, because they address different dimensions of the same problem.*

## 8.5. Creating conditions for financeable investments at reasonable costs

The decline in battery costs is one of the main factors explaining their rapid expansion worldwide. However, the cost of the technology is only one component of the cost of developing a project.

For Latin America and the Caribbean, the cost of capital can be equally important.

The bankability of an investment depends on the predictability of its revenues, the quality of counterparties, the contractual allocation of risks, and the stability of the regulatory framework. But it is also influenced by broader factors that extend beyond the energy sector, such as country risk, macroeconomic conditions, legal certainty, regulatory stability, and institutional quality.

As a result, technically similar projects with comparable equipment costs may face significantly different financing costs depending on the country in which they are developed.

This difference is particularly important for capital-intensive technologies. A decline in the international cost of batteries does not necessarily translate into the same reduction in the cost of energy storage across all countries if financing conditions differ.

A simple way to express this reality is:

> *The cost of technology may converge globally; the cost of capital continues to reflect the conditions of each country.*

A regional agenda for energy storage must therefore pay attention both to revenue signals and to the cost at which those revenue expectations can be translated into a financeable investment.

Certain risks can be reduced within the energy sector itself through regulatory stability, transparent procedures, clear contracts, creditworthy counterparties, and an appropriate allocation of responsibilities. Other risks lie beyond the scope of energy policy and require different instruments.

Where appropriate, guarantees, risk-mitigation mechanisms, concessional financing, blended finance structures, and the participation of multilateral development banks can help improve financing conditions.

> *The objective should not be to eliminate all risk for the investor, but rather to allocate it to those best positioned to manage it and to prevent unnecessary risks from increasing the final cost of flexibility for the system and consumers.*

## 8.6. Building information and capabilities for a new stage

Finally, there is a cross-cutting condition: it is not possible to adequately plan, value, and remunerate what cannot be measured.

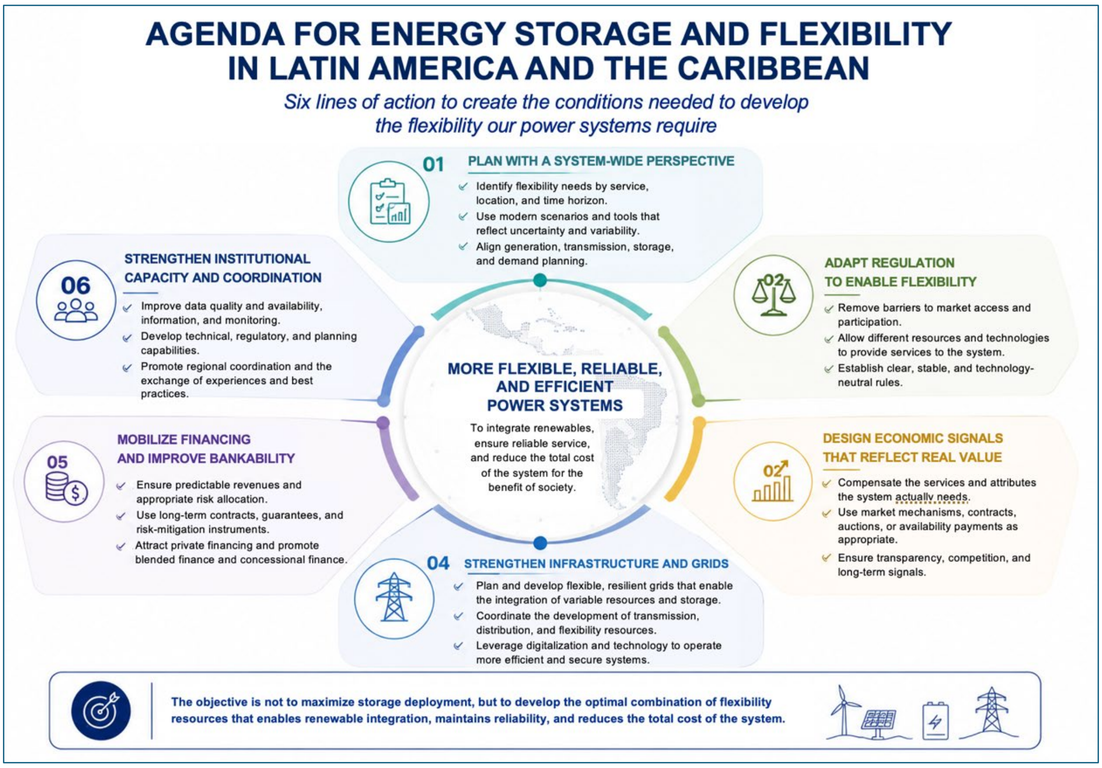
The growing deployment of energy storage requires increasingly detailed information on system operations, prices, congestion, curtailment, reserve requirements, charging and discharging profiles, availability, and asset performance.

The experience of markets such as Australia and California is particularly useful, not only because of the amount of energy storage they have deployed, but also because the availability of information makes it possible to observe how batteries are modifying system operations, prices, and their own revenue sources.

For Latin America and the Caribbean, strengthening the collection, systematization, and publication of information may be just as important as certain regulatory reforms.

Institutional capacity will also be needed to incorporate these new developments into planning and regulation. System operators, regulators, ministries, companies, and planning agencies will need to analyze power systems in which generation, demand, networks, and energy storage interact in increasingly dynamic ways. This includes learning from the region's own experience.

*Figure 9 Agenda for Energy Storage and Flexibility in LAC*




The progress beginning to emerge in some countries will provide evidence on system operations, prices, contracting models, technical performance, and regulatory responses under conditions specific to Latin America and the Caribbean. Systematically documenting these experiences will help build regional knowledge and reduce dependence on lessons drawn exclusively from power systems with different characteristics.

Regional cooperation and organizations such as OLACDE can play an important role in this process by collecting information and facilitating the exchange of methodologies, regulatory experiences, and project results.

# 9. A new stage: from energy storage to flexibility

Energy storage is no longer a marginal technology in power systems. The rapid expansion of BESS across different markets demonstrates that they can play an important role in integrating renewable energy, shifting energy over time, providing ancillary services, and managing certain system constraints.

But its growth is revealing something equally important: when energy storage reaches scale, it ceases to be merely a response to market conditions and begins to transform them as well. It modifies charging and discharging profiles, influences price formation, reduces certain hourly price differentials, and increases competition for some services that initially represented important sources of value.

This dynamic requires energy storage to be viewed from a different perspective. The economic conditions that justify an investment today will not necessarily remain unchanged throughout the asset's useful life. At the same time, the value that energy storage provides to the system cannot always be fully captured by the investor. Planning, regulation, market design, and procurement mechanisms therefore play a central role in connecting system needs with signals capable of mobilizing efficient investments.

For Latin America and the Caribbean, this discussion comes at a particularly timely moment. The region is still at a relatively early stage of BESS incorporation and can draw on the experience of power systems that have advanced more rapidly, not to replicate their solutions, but to anticipate some of the challenges that emerge when energy storage reaches significant scale.

The diversity of the region's power systems makes it impossible to establish a single pathway. Systems with a high share of hydropower, markets with growing solar and wind penetration, island systems dependent on imported fuels, and networks with transmission constraints face different needs. Consequently, the solutions and combinations of resources capable of providing the required flexibility will also differ.

> *The central question, then, is no longer how much energy storage should be installed. The question is what flexibility each system needs, where and when it needs it, what attributes are required, and which resources can provide it efficiently.*

This shift in perspective has profound implications. It means moving from technology targets to system needs; from remunerating assets to recognizing services and attributes; from looking only at current revenues to considering their evolution and bankability; and from evaluating energy storage in isolation to comparing and coordinating it with flexible generation, demand response, transmission, interconnections, and other alternatives. The sequence developed in this Note: system need, required service, technical characteristics, available alternatives, valuation, economic signal, and investment summarizes this new approach.

Energy storage will undoubtedly play an increasingly important role in the power systems of Latin America and the Caribbean. But the objective should not be to maximize the number of batteries installed. The objective is to build power systems that are sufficiently flexible to safely, efficiently, and sustainably integrate a growing share of renewable energy.

From this perspective, the new stage that is beginning is not only about energy storage. It is the age of flexibility.

FINAL MESSAGE

**The challenge for Latin America and the Caribbean is not to incorporate energy storage as an end in itself, but to build systems capable of identifying, valuing, and adequately remunerating the flexibility they need.**

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