Incorporation of Energy Storage in Power Systems

International Experiences in Regulatory Models

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Foreword

Energy storage systems (ESSs) are essential for the decarbonization of energy systems since they constitute an extremely versatile tool for giving the systems flexibility. The greater participation of intermittent renewable energies such as solar and wind energy requires greater flexibility in the power systems to maintain a steady balance of generation and demand. Energy storage plays a key role in this respect since it can act as a load or alternative electrical power source to offset the fluctuations of both generation and demand. ESSs can also alleviate problems of congested power transmission grids and postpone investment in transmission and distribution grids, among other things.

In Latin America and the Caribbean (LAC), storage plays an essential role in driving the transition to cleaner energy sources, improving resilience in the power grid, and providing access to energy in remote areas. It also contributes to the region's economic development and energy security while meeting the goals of sustainability and reduced greenhouse gas (GHG) emissions.

Several ESS projects have already been developed in LAC that have not required many regulatory adjustments. Such is the case of various "behind-the-meter" applications in Colombia, Chile, the Dominican Republic, and Peru. At the Inter-American Development Bank (IDB), however, we recognize that the use of all ESS applications requires regulatory frameworks that adapt to the realities of each country's energy markets.

To support the development of regulatory frameworks for energy storage, IDB contracted a consultancy for recommendations on how to update regulatory frameworks and market designs, including an adequate definition of ESS and a classification of assets (generation, transmission, or independent) to create a favorable environment that can encourage investment in ESSs. These recommendations were the result of an analysis of regulatory and market barriers hindering the adoption of ESSs and an evaluation of regulatory framework experiences in other regions such as Europe, the United States, and Australia. The consortium in charge of the consultancy consisted of MRC Consultants, PSR Energy Consulting and Analytics, and Siglasul Consultoria.

The results of this consultancy are summarized in this learning material entitled “Regulatory Frameworks for the Incorporation of Energy Storage in Power Systems: International Experiences in Regulatory Models,” which gives an analysis of ESS regulation in various markets in Europe, the United States, and Australia as well as preliminary regulatory experiences in this area in LAC.

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Acronyms

LAC	Latin America and the Caribbean
ANEEL	National Electrical Energy Agency (Agencia Nacional de Energía Eléctrica)
IDB	Inter-American Development Bank
BTM	Behind the meter
CAISO	California Independent System Operator
EC	European Commission
CDEC-SING	Economic Load Dispatch Center of the Big North Interconnected System (Centro de Despacho Económico de Carga del Sistema Interconectado del Norte Grande)
ERCOT	Electric Reliability Council of Texas
U.S.	United States of America
GHG	Greenhouse gases
GW	Gigawatt
ISO	Independent System Operator
MW	Megawatt
MWh	Megawatt hour
ESSs	Energy storage systems
BESSs	Battery energy storage systems
LDS	Local distribution system
NTS	National transmission system
RTS	Regional transmission system
EU	European Union
UPME	Mining and Energy Planning Unit (Unidad de Planeación Minero Energética)

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Introduction

Despite playing an essential role in the decarbonization of the energy sector and the subsequent reduction of GHG emissions, energy storage faces a number of regulatory barriers in energy markets that hinder its development, to wit: (i) The lack of a clear regulatory definition in regulatory frameworks limits the possibility of offering and adequately compensating the many services offered by ESSs. For example, when ESS installations are specifically classified as generation assets it impedes compensation for other services that ESSs can provide, such as frequency control; (ii) Inadequate price and rate schedules make compensation for ESSs difficult; and (iii) The lack of markets for ancillary services, black start, or inertia also limits the compensation and business models that ESS investors could develop.

This document presents a synthesis of international experiences in ESS regulation in markets with high storage penetration for the purpose of identifying key regulatory elements that might favor the speedy adoption of ESSs in LAC countries. The energy markets considered were the United Kingdom, Spain, France, Italy, and Germany in Europe, California and Texas in the United States, and Australia.

The document is divided into five chapters, including this introduction. The second chapter analyzes the approach and critical elements of the ESS regulatory models through a review of the selected markets. The analysis identifies the following: (i) the main energy market regulatory issues affecting ESS development; (ii) specific regulatory elements for energy storage; (iii) regulatory elements for opening the energy market to ESSs; and (iv) regulatory elements that give economic viability to storage projects.

The third chapter gives the key elements of ESS tariff frameworks that have been developed in the study markets and identifies potential regulatory barriers. This chapter presents a comparison of the storage tariff frameworks for the study markets.

The fourth chapter introduces significant ESS regulatory cases with a detailed analysis of the Chilean and Colombian cases, as well as the progress made in Brazil. The section is supplemented by a table that summarizes the regulatory progress in Brazil, Chile, Colombia, the Dominican Republic, and Mexico along with the sources of information on these experiences.

Finally, the fourth section gives the conclusions on the lessons learned from the case studies, considering the main barriers and regulatory challenges for ESS development and the best practices for overcoming them, that could be applied in LAC countries.

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Regulatory Models for Storage: Approaches and Critical Elements

Historically, energy markets and their regulation have evolved with a vision of manageable centralized systems. Given this structure, there are several major challenges for incorporating ESSs into the power system so that they can participate in these markets with adequate compensation. For storage technologies to be developed and installed, a regulatory framework is needed that recognizes and adequately remunerates the services these systems provide. An appropriate regulatory environment plays an essential role in attracting storage investments and managing the associated demand.

Best regulatory practices indicate that a regulatory framework for storage should be developed on the basis of technological neutrality and diversified business models and designed under the general criteria of simplicity and economic efficiency. Power system decarbonization and renewable energy source penetration goals and targets, as well as improved energy supply security and quality, should also be considered.

This section presents a review of the general principles that any regulatory energy storage framework should consider and then analyzes international experiences with the application of these general principles.

The countries reviewed as having best practices include the United Kingdom, Spain, France, Italy, and Germany in Europe, the United States (California Independent System Operator (CAISO) and Electric Reliability Council of Texas (ERCOT)), and Australia. Two criteria were used in the selection of best practices: i) level of storage market maturity (experience in operational storage applications and projects); and ii) level of regulatory development.

2.1 Key Elements of a Regulatory Framework that Enables the Incorporation of Energy Storage

As with any power system asset, ESSs are subject to different levels of rules and regulations ranging from the sector's framework law to operational procedures and grid codes. The regulatory framework's design for incorporation of energy storage varies among countries and markets (as we will see in section Error! Reference source not found. on international experiences). However, there are several minimum elements that any framework should consider.

This section describes the key elements of a regulatory framework for storage without going into details on the regulatory range that each should have (this will be described in the analysis of international experiences). The regulatory framework that affects storage can be summarized into the following levels:

1. **General power system regulation.** Storage development and operation, like any electricity sector agent, will be conditioned by market design and scheme, regulation of unbundling and transmission, distribution, and marketing activities, grid access, market participation, wholesale price formation, retail price signals, etc.

2. **General energy storage regulatory framework.** Regulatory fit of storage within the sector's regulatory framework:

    a. **Definition, ownership, and operation:** related to the sector's unbundling scheme.

    b. **Storage configuration:** large-scale treatment of storage (front of the meter) connected to the transmission and distribution grid versus storage behind the meter (BTM).

    c. **Legal security:** Rights and obligations of a storage asset within the sector.

    d. **Market opening and non-discrimination.** Non-discriminatory treatment of storage compared to other sector agents, whether generators or demand.

3. Specific regulatory elements for storage

a. **Project development:** Laws and regulations that affect project development from planning to implementation.

   i. Treatment of storage for the purposes of access and connection to the transmission, distribution, and BTM grid. Permits and assignment of grid capacity. Technical connection and test requirements.

   ii. Administrative authorization and paperwork. Administrative procedures for obtaining all permits for facility construction and operation.

   iii. Environmental criteria and evaluation related to the paperwork phases. Each jurisdiction imposes different environmental impact evaluation procedures and requirements.

b. **Market participation:** Regulation that conditions participation in the different storage markets:

   i. Market opening;

   ii. Requirements and forms of market participation; and

   iii. Treatment of hybrid generation facilities with storage for the purpose of market participation: grid load vs. plant load.

c. **Economic viability - tariff framework.** Revenue system under which storage can operate:

   i. Available markets and revenue stacking: energy arbitrage, capacity payment, frequency control, reserves, etc.

   ii. Available aid and incentives: specific revenue lines for storage such as auctions or financial support (subsidies).

The following figure illustrates and summarizes the points explained above.

Figure 1 – Key Elements of the Energy Storage Regulatory Framework

Source: MRC, Consultancy Study "Development of Energy Storage Regulatory Frameworks" RG-T3801-P001

General Electricity System Regulation

Storage development and operation, like any electricity sector agent, will be conditioned by market design and scheme, unbundling regulations, grid access, market participation, wholesale price formation, and retail price signals, etc.

General energy storage regulatory framework: regulatory fit of storage within the sector's regulatory framework:

a. Definition, ownership, and operation: related to the sector's unbundling scheme.
b. Storage configurations: treatment of large-scale (generation and transmission) and small-scale storage; front-of-the-meter and behind-the-meter (BTM) storage.
c. Legal certainty. Obligations and rights of a storage asset within the sector.
d. Market opening and non-discrimination. Non-discriminatory treatment of storage compared to other sector agents, whether generators or demand.
e. Project initiative and allocation: planning/allocation through auctions and liberalized development.

Possibility of operating ALM as a regulated grid-integrated asset

Development of ALM projects. Laws and regulations that affect project development from planning to implementation:

- **Access and connection** to the transmission, distribution, and BTM grid. Technical connection and testing requirements
- **Permit processing and administrative authorization:** permits for construction and operation of the installation
- **Environmental evaluation and procedures**

Market participation. Regulation that conditions participation in the different storage markets:

- **Market opening**
- **Requirements** and forms of market participation
- Treatment of hybrid installations of generation with storage for market participation purposes: **grid charge versus plant charge**
- BTM or retail participation scheme (combined with self-consumption)

Economic viability – tariff framework. Revenue scheme under which storage can operate:

- Available markets and revenue stacking: energy arbitrage, capacity mechanism, frequency control, reserves, etc.
- Retail tariff scheme: BTM ALM (stand-alone or with self-consumption)
- Incentives and available aid, specific revenue lines for storage

Legal security is essential to the development of storage in any system, so any regulatory framework should be capable of addressing at least the issues presented in Table 1 concerning the definition, ownership, and operation of energy storage. The table also shows how the regulatory practices analyzed in Europe, the United States, and Australia address these regulatory issues.

Table 1. Main Regulatory Issues that Affect Storage

REGULATORY SCOPE	REGULATORY ISSUE	RESPONSE ACCORDING TO ANALYZED BEST PRACTICES
Storage Definition, Ownership, and Operation	Definition of storage and regulatory fit	Most of the analyzed regulatory experiences include a definition of storage as an agent of the electric power sector within their regulatory frameworks. The definition of storage tends to center on its dual capacity to generate and consume energy and its potential for deferring consumption over time and later injecting it into the grid. • European Directives definition: Storage defers the final use of electricity to a moment later than when it was generated. • California (CAISO): Storage is defined within the category of Non-Generator Resources (NGRs), which are resources that operate as either generation or load (demand).
	Treatment of storage as generation and/or demand	The general definition of storage includes its dual nature as generation and demand, defining it as an individual agent of the sector. Lower-order regulatory elements (such as grid codes and market rules) do consider differently the activities of generation and use when defining the technical, legal, and commercial requirements for grid connection and market participation.
	Storage definition and technologies	The best international storage regulatory practice is based on technological neutrality; that is, all storage technologies receive the same regulatory consideration. Likewise, storage should be considered in a non-discriminatory manner with regard to generation and consumption technologies in the markets/services in which it participates. The regulatory approach should center on meeting the system's needs, defining the necessary technical requirements for participation in energy markets and delivery of ancillary services. Once needs or requirements are defined, regulation should not discriminate between technologies and the decision between one option or another should be based on technical and economic criteria.
	Consistency among laws / general definition and regulations, grid codes, etc.	The definition of storage tends to be included in the sector's framework law on which sectoral codes and regulations depend. The definition and general consideration of storage should be sufficiently precise to ensure legal security while at the same time leaving regulatory margin for lower-order legislation of regulatory and operational details. In best regulatory practice, the framework law defines storage in general terms without going into operational details.

REGULATORY SCOPE	REGULATORY ISSUE	RESPONSE ACCORDING TO ANALYZED BEST PRACTICES
Storage Definition, Ownership, and Operation	Who is authorized to own and operate storage assets?	In the studied systems storage is considered a liberalized activity or asset open to the operation and participation of liberalized market agents. Ownership and operation are regulated in general terms with the same approach as a generation asset.
	Can system/grid operators own and operate storage assets?	The studied systems are liberalized markets where the system operator cannot own or operate generation or consumption (or storage) assets. In general terms, storage assets cannot be operated by system/grid managers due to the competition problems associated with their being assets that participate in markets.
	Under what assumptions? Implications for competition?	Exceptions are permitted to this limitation if storage is used exclusively for managing grid congestion/problems (fully integrated grid asset). If the storage does not impact the dispatches / programs of each market agent it may be operated by the system manager(s) and receive regulated compensation for this activity.

Specific Regulatory Elements for Storage

Once energy storage is defined in the regulation, specific regulatory elements need to be established for project viability. Regulatory barriers should be eliminated and appropriate signals of long-term regulatory stability should be given to companies, investors, and financial institutions so that they can accurately assess the risk involved in storage projects.

From the review of international regulatory practices it was possible to divide the specific regulatory elements of energy storage into three groups:

- Regulatory elements for the development of storage projects;
- Regulatory elements for opening up the storage market; and
- Regulatory elements for the economic viability of storage projects.

Tables 2 through 5 below present the specific regulatory elements identified for storage promotion according to these three groups. The tables give the regulatory scope/topic, the regulatory question/issue faced by regulators, and the responses given to these issues by best international practices.

Regulatory elements for the development of storage projects. These are the laws and regulations that affect project development from planning to implementation; they are given in Table 2 and can be grouped as follows:

- **Treatment of storage for the purposes of access and connection to the transmission, distribution, and BTM grid.** Permits and assignment of grid capacity. Technical connection and test requirements.
- **Administrative authorization and paperwork.** Administrative procedures for obtaining all permits for facility construction and operation.
- **Environmental criteria and evaluation.** This is related to the paperwork phases. Each jurisdiction imposes different environmental impact evaluation procedures and requirements.

Table 2. Regulatory Elements for the Development of Storage Projects

REGULATORY SCOPE	REGULATORY ISSUE	RESPONSE ACCORDING TO ANALYZED BEST PRACTICES
Project authorization and permitting process	What treatment is given to storage projects for getting permits and authorization?	In most of the analyzed regulatory experiences, energy storage would receive the same treatment as other forms of generation. Connection of storage projects follows the same steps and requirements as a generation project.
Environmental criteria and evaluation	Environmental evaluation requirements	In general terms the same environmental evaluation criterion is applied as with generation projects. There are certain simplified procedures depending on the size of the project, degree of impact, and if it is hybridized with generation assets.
Access and connection	What treatment is given to storage for connecting to the grid?	Similar to the permitting process and authorization of storage projects, connection of storage projects follows the same steps and requirements as a generation project.
	Access and connection of hybridized storage	There are certain simplified procedures depending on the size of the project, degree of impact, and if it is hybridized with generation assets.
	Technical requirements: grid codes	The technical connection requirements (grid codes) applicable to storage take into account its dual nature as generator and demand. Grid codes do not discriminate between storage and other agents.

Regulatory elements for opening up the storage market. These are for regulating and conditioning opening and participation in the different markets for the services offered by energy storage; they are presented in Table 3 and refer to the following:

- Market opening;
- Requirements and forms of market participation; and
- Treatment of hybrid generation facilities with storage for the purpose of market participation: grid load vs. plant load.

Table 3. Regulatory Elements for Opening up the Storage Market

REGULATORY SCOPE	REGULATORY ISSUE	RESPONSE ACCORDING TO ANALYZED BEST PRACTICES
Market opening (system fees and charges)	What system fees and charges apply to storage? Application of fees to recharges? Application of charges to discharges?	This is one of the regulatory issues on which regulatory approaches differ the most. The regulatory approach to storage is related to the general approach to fees and charges: costs for power/energy and assignment of fees to consumption/generation. The most widespread approach is to apply consumption fees and charges to storage facilities, but there are major differences. In some countries (Spain) storage is exempt from payment of fees for consumed energy that is reinjected, in France a fee is paid for both consumption and injection, and in Germany there are special rate categories for storage.
Market participation	In what markets can storage operate?	The general approach of the studied best practices is that storage should be able to participate in all markets and services in which it is technically qualified according to the principle of technological non-discrimination. Storage should be able to participate equally with generation and demand assets. The best regulatory practices aim at full market opening (energy, capacity, frequency control services, etc.) for storage, which should compete in a non-discriminatory manner with other agents. The markets in which it can participate will depend on the scheme of current services/ dispatch/markets in each system/market.
	Market participation requirements	The same participation requirements are applied to storage as to any market agent: generation or demand. With ancillary services, the same enabling criteria applies as for any other service provider (generation).

REGULATORY SCOPE	REGULATORY ISSUE	RESPONSE ACCORDING TO ANALYZED BEST PRACTICES
Integration with other technologies - hybridization	Approach to hybridization of storage with generation	In most of the analyzed regulatory experiences there are incentives for developing projects that integrate co-located storage with generation assets under certain conditions such as geographical proximity and the same connection point.
	Under what conditions is hybridization of generation with storage permitted and able to act?	In general, the treatment of hybridization is given storage assets that share a grid connection point with a generation asset or assets. Depending on the jurisdiction, several geographical proximity criteria apply (10 km in Spain). The treatment of hybridization (as against stand-alone storage) varies from one system to another with regard to interconnection, permitting process, and operation.
	Impact on grid access and connection: hybridized vs. stand-alone storage	In most of the analyzed regulatory experiences, the procedures for access and connection to the grid can be processed together for hybrid facilities that include storage. Generation and storage share capacity and connection point. If storage is added to existing plants, additional capacity can be requested (if available) or the conceded access capacity can be used by updating the interconnection permit. Interconnection requirements (grid codes) are applied to the entire facility (generation + ESS) or to each facility separately depending on the physical connection characteristics.
	Impact on the authorization and permitting process: hybridized vs. stand-alone storage	New projects can combine the permitting process for generation with storage. Adding storage capacity to a generation project requires a separate authorization but the environmental evaluation process tends to be simpler than for generation due to the relatively minor environmental impact.
	Impact on operation: hybridized vs. stand-alone storage	The main regulatory issue of hybridization is whether or not the storage can be charged from the grid or can only be charged from the hybrid plant's production. The international experiences vary, but the most advanced regulatory schemes permit charging from the grid provided it is technically and commercially viable, with meters and an adequate payment scheme. For example, a generation plant with a regulated rate should be capable of discriminating renewable resource production from storage production.

Regulatory elements for the economic viability of storage projects. This refers to regulations that establish a revenue scheme under which the storage can operate and the project is economically viable. These are presented in Table 4 and can be grouped into three categories:

- Available markets and revenue stacking: energy arbitrage, capacity payment, frequency control, reserves, etc.;
- BTM or retail participation schemes (combined with self-consumption); and
- Available aid and incentives: specific revenue lines for storage such as auctions or financial support (subsidies).

Table 4. Regulatory Elements for the Economic Viability of Storage Projects

Source: MRC

REGULATORY SCOPE	REGULATORY ISSUE	RESPONSE ACCORDING TO ANALYZED BEST PRACTICES
Compensation for services / capacities	Existing system services/markets Existing system services/markets Revenue complementarity: revenue stacking	This depends on each system. In all the analyzed systems storage can at least participate in arbitrage in the wholesale market and balance/frequency control services. The analysis of international experiences identified the following revenue lines as essential for storage to cover its investment and operating costs: • Energy arbitrage; • Capacity mechanism. Capacity payment is key revenue for giving long-term certainty to the promoter and remunerating the contribution of storage to supply security. In several of the analyzed experiences (California, Italy, United Kingdom, and France) the assignment of a long-term guaranteed capacity payment facilitated deployment of the storage; and • Balance/frequency control services. The modularity and fast response (to ups and downs) of batteries make them a competitive agent for providing frequency control services to system operators. Together with arbitrage, this is the main application of batteries in the world's commercial business models.
Wholesale tariff scheme	Liberalized/ regulated prices	In all the analyzed systems, wholesale prices are set in a liberalized manner by market instruments.
	Nodal pricing	To this respect there are differences among the analyzed experiences. In Europe, the systems work with single node pricing while in the United States they work with nodal pricing. This point has significant implications for each power system's design and should be analyzed with a comprehensive view of the entire sector and all its agents (generation, system operation, consumption, and storage). The potential and limitations of nodal pricing should be evaluated within each country/region's overall decarbonization strategy. In systems with geographical resource flexibility, nodal pricing provides adequate price signals for optimizing the development of generation, transmission grid, and storage. In other systems where the renewable resource is geographically concentrated (hydro, wind, and solar in some regions), zonal pricing can discourage generation and a single pricing system with combined generation and transmission planning may be optimum. Generally speaking, given their operational and location flexibility, most storage technologies benefit from both temporally and geographically granular market designs (nodal pricing).

REGULATORY SCOPE	REGULATORY ISSUE	RESPONSE ACCORDING TO ANALYZED BEST PRACTICES
Public support and planning	Role of storage within energy planning	In all the analyzed experiences, storage is part of energy generation and transmission planning. Generation in the analyzed countries is developed in a liberalized manner, but indicative plans exist with goals for renewable development together with storage capacity. In all energy planning, storage is recognized as important for permitting greater renewable penetration in compliance with security standards for supply, reliability, and system stability. Transmission investment planning is liberalized in the U.S. but must follow harmonized directives in Europe. In the analyzed experiences, the latest expansion plans of transmission managers include storage as a key element of the system that affects investment decisions in transmission assets. Some grid managers (Germany) have experience using storage as virtual transmission lines, replacing or delaying investment in lines.
	Incentives and specific financial support (subsidies)	Most of the analyzed systems have certain mechanisms in place to help ensure the commercial viability of storage investments. In Europe, the preferred system is capacity auctioning whereby a fixed payment is assigned during a certain length of time (5-15 years) for storage assets. In recent years, to speed up decarbonization Europe has loosened its regulation of state aid to permit subsidizing of storage development. In the United States, the preferred approach of public aid is based on tax exemptions.
BTM storage - BTM self-consumption	Retail tariff scheme	BTM storage potential is conditioned by retail rate setting methods and schemes (wholesale pricing plus grid fees and accesses). There are significant differences to this respect among the studied tariff schemes. A key conclusion is the positive relationship between hourly discrimination and incentives for behind-the-meter storage. With respect to cost allocation between energy and power, the international experiences vary. In certain systems there are experiences of commercial BTM storage applications to reduce charges for power (peak shaving), while cases also exist of storage use for arbitrage.
	Regulation of generation for self-consumption	In most systems with high penetration of BTM storage (Germany and Australia), this has been developed together with the installation of generation for self-consumption. With respect to self-consumption and storage, regulation should: • Provide incentives for the development and installation of self-consumption and eliminate regulatory and technical barriers; and • Design adequate surplus settlement schemes for the system that provide incentives for optimizing BTM energy.

REGULATORY SCOPE	REGULATORY ISSUE	RESPONSE ACCORDING TO ANALYZED BEST PRACTICES
BTM storage - BTM self-consumption	Self-consumption surplus settlement schemes	Net metering schemes do not tend to incentivize storage of surpluses by settling all energy at the same tariff. Net billing schemes incentivize the use of self-production by limiting surpluses.
Supervision	Storage activity monitoring	In all the analyzed experiences, the storage activity is monitored by the same entities responsible for supervising the generation and wholesale market sector: the regulator, system/grid (transmission or distribution) manager, and/or ministry.
	Storage capacity information	In all the analyzed experiences there are records of front-of-the-meter storage (after a certain size) managed by the system operator and/or ministry or competent administration.

2.2. International Experiences in Regulatory Frameworks for Storage

Having defined the key elements of the regulatory framework and institutional system for storage, in this section we will see detailed examples of their application. To this end we selected different countries and systems that ensure a pluralistic analysis of the different approaches and regulatory practices. We took into account two criteria in our selection of international experiences:

1. Experience in developing and integrating different storage technologies. Countries with greater installed storage capacity; and

2. Level of maturity of the regulatory framework for storage systems. Enabling regulatory framework for the development of commercially viable storage projects.

The following map illustrates the selection of experiences to be analyzed in this section.

Figure 2. International Experiences

Source: MRC

2.2.1 European Countries

The European Union (EU) is a paradigmatic case of policy and regulatory integration where the energy sector is one of the dimensions in which the most progress has been made on achieving harmonized market rules. The regulation for the internal electricity market sets the general rules for the sector's future development in all member countries.[1] Any regulatory analysis of EU countries, then, should consider the following two regulatory scopes:

European Union. At the EU level, the European Commission (EC) and Parliament have approved regulations and directives that require mandatory compliance by member states through transposition into national law. EU regulation sets the sector's directives and general regulatory principles.

National regulation. Although European regulation must be transposed in its entirety, member states are left a margin for regulatory action on issues such as project permitting processes or storage payment schemes.

The two approaches, European and national, are considered in the international analysis of European experiences in storage regulation, and the regulatory frameworks of Spain, Italy, France, Germany, and the United Kingdom are described in detail.[2] (See Table 5).

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1 https://www.boe.es/doue/2019/158/L00125-00199.pdf

2 Although the United Kingdom has been out of the single European energy market since 2021, the critical regulatory framework elements for storage were defined earlier in accordance with EU directives. The country's energy regulation is therefore included within the EU framework.

Table 5. Summary of the Regulatory Framework for Storage in European Countries

	United Kingdom	Spain
Storage status	European leader in installed batteries: >3 Gigawatts (GW)	The battery storage sector has been booming since regulatory barriers were lifted (2020-2022).
Definition of storage	Conversion of electrical energy into a form of energy that can be stored, the storing of such energy, and the subsequent reconversion of that energy into electrical energy	European Directives definition: Deferring the final use of electricity to a moment later than when it was generated
Project authorization and permitting process	Electricity storage would receive the same treatment as other forms of generation. Exempt electricity storage (excluding pumped hydro) from the regime of nationally important infrastructure projects, implying that extensive approval processes were no longer necessary for battery energy storage systems (BESSs) exceeding 50MW.	The permitting process for storage projects follows the same steps as those of generation. A harmonized environmental evaluation criterion is pending regulation.
Hybridization with renewables: co-location	Working on how renewable energies can be better integrated and identifying the barriers for co-location of storage with generators with contracts for difference (CFDs).	Hybridization: adding storage to the same interconnection permit. It can charge and discharge from the grid.
Grid fees, charges, and other rates	Elimination of double charge for charging/discharging electricity and elimination of charges to the end consumer.	Exempt from paying fees and charges for use of the grid since these affect the end consumer.
Business model Tariff framework - revenue stacking New services/ revenue	There are no long-term subsidies or fixed income contracts available for storage so storage development is sustained by market revenue. Different frequency control services. • Capacity payment • Energy arbitrage • Voltage monitoring Most varied revenue framework in Europe	Storage can participate in energy and frequency control markets. The tariff framework of storage in Spain is one of the least developed in large European markets since it does not pay for either capacity or fast response the way countries like the United Kingdom, France, or Italy do.
Links	https://www.legifrance.gouv.fr/jorf/id/JORF-TEXT000043956924 https://www.legifrance.gouv.fr/jorf/id/JORF-TEXT000045766492	https://www.boe.es/eli/es/o/2021/12/22/ted1447 https://www.boe.es/buscar/act.php?id=BOE-A-2015-10927

Germany	Italy	France
>1 GW. European leader in installed batteries in the BTM sector	600 Megawatts (MW) / 1,200 Megawatt hours (primarily BTM MWh)	900 MW of battery storage projects announced for 2023
European Directives definition: Deferring the final use of electricity to a moment later than when it was generated	Designed for operating in the energy grid for the purpose of injecting or withdrawing energy	According to European Directives
Defined by federal environmental regulation. Recently, in December 2022, the European Parliament approved a legislative package that simplifies the permitting process and environmental evaluation.	The lack of clear time periods, permit procedures, and a specific environmental regulation is an obstacle.	The standard permitting rules for energy generation plants apply to storage plants.
They are increasingly being built in the same place as power plants based on renewable energies since this combination creates an advantage in terms of market premium for regulated facilities.	They can be connected to an electric power production plant, including plants of renewable energy sources.	Most of the large-scale storage developments are stand-alone (not tied to a generation facility).
Special tariff schemes for energy storage facilities.	Exempt from application of grid fees.	Should pay charges for distribution grid injection and withdrawal.
Storage participates in balance and frequency control services and provides the first response. “Innovation auctions”, use of batteries as virtual transmission lines.	Storage participates in energy and balance and frequency control markets. In 2021 and 2022, auctions were launched for allocating the provision of new services. • Fast frequency response • Capacity mechanism	Long-term capacity market contracted revenue: France. Frequency containment reserve, also known as primary control reserve.
https://www.bundesnetzagentur.de/EN/Home/home_node.html	https://www.gazzettaufficiale.it/eli/id/2021/11/30/21G00214/sg http://www.gazzettaufficiale.it/eli/id/2021/12/11/21G00233/sg https://climate-laws.org/documents/decree-law-172022-on-energy-support-1832?id=decree-law-17-2022-on-energy-support_3752	https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000043956924 https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000045766492

2.2.2 United States of America (U.S)

A particular feature of the U.S. system is its level of operational and regulatory decentralization organized into different independent system operators (ISOs). The ISO market has particular features that affect battery development, so we will center the analysis on the two systems with the most installed battery power as of November 2022: California (CAISO, the California Independent System Operator) and Texas (ERCOT, the Electric Reliability Council of Texas).

CAISO introduced the non-generator resource model in 2012 to permit the participation of energy storage resources in the wholesale market. As of May 2023, CAISO had somewhat more than 3,500 MW of storage capacity available for discharge in the CAISO market.[3] CAISO sees that these resources are charged primarily during periods of the day when prices are the lowest (when solar energy is abundant) and discharged during periods of the day when prices are the highest. At present, CAISO depends on storage resources for the critical operation of a local capacity area.

ERCOT stands out from other ISOs in the United States for its energy-only wholesale electricity market. Although there is no capacity mechanism in place, ERCOT is subject to similar requirements for maintaining adequate reserve margins to back up grid reliability. ERCOT has more solar and wind capacity than CAISO, which poses the need to manage non-manageable renewable energy generation. In 2019, ERCOT launched an active process of updating all its rules and regulations to facilitate the participation of storage. In terms of energy storage, its capacity reached 2,300 MW in May 2023.[4]

The regulatory framework elements for storage in CAISO and ERCOT are given in Tables 6 and 7.

[3] California ISO. Special Report on Battery Storage. July 7, 2023.
[4] Battery stampede spurs sunny storage economics in ERCOT. S&P Global Market Intelligence

2.2.3. Australia

Regulation for the development of energy storage in Australia is essential for ensuring a sustainable, reliable energy supply throughout the country. The key elements of this regulation include creation of a stable, predictable regulatory framework, implementation of measures to encourage the integration of renewable energy into the power system, and tariff frameworks for storage over other technologies. In addition, regulation includes measures for ensuring fair competition in the energy storage market by means of a competitive definition of storage. The regulatory framework elements for storage in Australia are given in Tables 6 and 7.

Table 2. Summary of the Regulatory Framework for Storage in the U.S. and Australia

	U.S. – California (CAISO)	U.S. – Texas (ERCOT)	Australia
Storage status	>3.5 GW in operation (leader in the U.S.)	>1 GW in operation. Leader in the U.S. counting projects in the permitting process	>1.6 GW in operation. >50% BTM
Definition of storage	Resources that operate as generation or demand. They can dispatch at any operational level within their range of total capacity, but they are limited by a MWh cap for (1) generating energy, (2) reducing energy consumption in the event of response to demand, or (3) consuming energy.	Provide dispatchable energy and/or ancillary services to the ERCOT system. It also requires energy storage resources to be recorded as generation resources and controllable load resources.	Energy storage is defined within the national rules for electricity. The definition of storage covers different electricity storage technologies such as pumped hydro, batteries, or flywheels.
Project authorization and permitting process	Interconnection must be requested from the grid operator (CAISO) or distribution grid operator. Project authorization is subject to environmental evaluation by the state government.	Interconnection request and evaluation at ERCOT: technical requirements. Environmental evaluation of the project.	Generation systems must be registered with the Australian Energy Market Operator. Systems will be classified by their characteristics. Hybrid generators with installed power of less than 30 MW and battery storage systems that do not exceed 5 MW are exempt from generator registration.

	U.S. – California (CAISO)	U.S. – Texas (ERCOT)	Australia
Hybridization with renewables: co-location	Almost all new solar projects in California include storage. Some 6 GW of new stand-alone storage capacity and 15 GW of renewable energy with storage have signed an interconnection agreement with CAISO.	More than 50% of the installed storage capacity is hybridized. New developments are aimed at stand-alone for managing and taking advantage of congestions.	Large-scale installations of different technologies that share a single grid connection point permit registration of the participant as a consumer and exporter of substantial amounts of electricity to or from the grid. Small customer aggregators are not considered.
Grid fees, charges, and other rates	Energy consumption by storage is subject to the same grid fees as any other consumer provided the consumption is not activated by ancillary service offerings.	Storage must pay fees and charges when consuming from the grid.	Prescribed service has a regulated price and standard service that are charges for use of the transmission system. Service negotiated with the transmission service provider has charges for use of the system even though they are not the prescribed transmission services.
Business model Tariff framework - revenue stacking New services/ revenue	Participate fully in the ancillary services market. Obtain payments for capacity and energy for ancillary services (AS), including spinning reserves, non-spinning reserves, and regulation. CAISO created a single function, Energy Management Regulation for ALM.	Revenue from energy arbitrage in nodal pricing. Frequency containment services. There is no capacity payment. ERCOT checks grid needs for defining new services and markets where storage can participate.	Energy arbitrage Resource adaptation: Add capacity to the grid to meet generation needs during demand peaks. Frequency regulation.

3

Business Models: Tariff Framework for Storage

Energy storage is a fundamental pillar of the energy transition, being essential for efficient integration of renewable energies and their increased use in decarbonization. Storage has potential for providing a wide variety of services to the system, ranging from energy arbitrage and frequency containment to grid congestion management.

Regulation should ensure this potential is optimally used by establishing an adequate tariff framework. The tariff framework for storage should be studied with attention to the value it contributes to the system and the following general criteria:

1. **Storage development viability:** The tariff framework should adequately value the services provided by storage. This service valuation should enable enough payment to help make storage developments economically viable while at the same time preventing overpayment that adds to costs for the system and consumers.

2. **Optimum use of storage:** The tariff framework for storage should give adequate signals and incentives to the storage operator to optimize storage potential.

Beyond ensuring its participation under equal conditions in the different markets and services existing in each system, the characteristics of storage make it, in turn, a catalyzer of new business models that facilitate its deployment and add value to the different energy transition elements. The business models and applications should be considered from the viewpoint of system optimization so that the needs of the system are efficiently met. The tariff framework for storage should therefore be seen as being dynamic with regulation that continually evolves with the changing needs of the system.

Table 7. Key Elements of the Tariff Framework for Storage

Source: MRC

Market / Revenue	Service/Market Characteristics Storage Opportunities	Regulatory Approach	Regulatory Barriers	Typical Storage Requirements
Energy arbitrage	Participation in the wholesale energy market. Scheduled storage charge and discharge according to wholesale energy market prices or costs. Charges in low-price hours (high renewable penetration) and discharges in high-price hours. Payment for activation.	Regulatory neutrality for storage compared to other wholesale market participants.	General storage participation limitations. Without additional costs or barriers that penalize storage (double taxation or double charge for charges/discharges).	Storage duration: 1-8 hours Response time: not critical Installed or aggregate capacity: according to wholesale market regulations (>1 MW).
Frequency containment - balance services - spinning reserve	Storage charge and discharge activated according to the balance and frequency containment needs. Opportunity to receive payments for availability plus balance energy activation: charges cheaper than market and sales more expensive. Payment for activation and availability.	Regulatory neutrality for storage compared to other balance and frequency containment service providers.	Without additional costs or barriers that penalize storage (double taxation or double charge for charges/discharges).	Storage duration: >2 hours Response time: depending on the service (<1 min) Installed or aggregate capacity
Capacity mechanism	Payment for availability associated with the storage discharge/sell capacity during high stress hours of the system (demand peaks, supply security risks, etc.). Payment for firm power availability (storage hours)	Incentivize storage as a zero-emissions technology (if it charges from renewables) to provide firmness compared to conventional alternatives (gas, coal, etc.).	Lack of payments for capacity. Inadequate capacity market regulations. Lack of incentives for storage compared to fossil fuel generation Barriers to hybridization of renewables with storage.	Storage duration: 1-8 hours Response time: not critical Installed or aggregate capacity: according to capacity market regulations (>1 MW).

Market / Revenue	Service/Market Characteristics Storage Opportunities	Regulatory Approach	Regulatory Barriers	Typical Storage Requirements
Fast frequency response	Storage charge and discharge activated according to fast response needs (<15 seconds) of frequency containment that cannot be satisfied with balance services. Supplements the inertial response of synchronous generators. Payment for activation and availability.	Regulatory neutrality for storage compared to other fast response service providers.	Without additional costs or barriers that penalize storage (double taxation or double charge for charges/discharges). Inadequate payment for activation that entails battery degradation.	Storage duration: <1 hour Response time: depending on the service (<15 seconds) Installed or aggregate capacity: depending on balance service regulations (>1 MW)
Virtual lines / Replacement of investments in the transmission and distribution grid	Inclusion of storage as a grid asset for replacing/delaying investments in lines and substations. Include storage as a planning alternative to investment in transmission assets.	Encourage evaluation of the ALM as an asset in grid planning.	Barriers to the use of storage as a grid asset.	Storage duration: >2 hours Response time: not critical Installed capacity: variable according to the grid
Management of operational technical restrictions	Battery activation to respond to price signals of congestion - technical restrictions. Payment for activation. Nodal pricing vs. single pricing + congestion pricing	Encourage the use of storage to manage operational and technical restrictions	Barriers to participation in congestion markets.	Storage duration: 0.5-8 hours Response time: not critical Installed capacity: variable according to the grid

Market / Revenue	Service/Market Characteristics Storage Opportunities	Regulatory Approach	Regulatory Barriers	Typical Storage Requirements
Voltage monitoring / reactive power	Offer voltage monitoring / reactive power services to the system operator. Payment for availability and/ or activation.	Adequate price signals for paying for voltage monitoring in critical nodes. Market opening and technological neutrality	Lack of payment for voltage monitoring. Market closed to storage.	Storage duration: < 2 hours Response time: < 1 min. Installed capacity: > 1 MW.
Local markets	Offer flexibility services (balance and congestion management) in local markets at the distribution level. Payment for availability and/ or activation.	Opening and development of local flexibility markets.	Lack of local markets.	Storage duration: 0.5-8 hours Response time: < 1 min. Installed capacity: > 100 kW
Energy billing	BTM storage. Billing, charge management, peak shaving, reduction of capacity fees. Combination of self-consumption generation and demand response.	Adequate incentives and price signals for incentivizing demand response, self-consumption, and combination with storage.	Failures in the regulation of self-consumption. Lack of hourly price signals for end consumers.	Storage duration: 1-4 hours Response time: not critical Installed capacity: <1 MW.

Table 8 gives the different revenue lines and their availability in each analyzed European market.

Table 8. Comparison of European Experiences: Tariff Framework and Business Models

	United Kingdom	Spain	France
Daily market arbitrage	High energy arbitrage opportunities: high volatility	Few current opportunities: increasing as renewable penetration rises.	High arbitrage opportunities due to price volatility caused by nuclear production rigidity.
Balance - frequency containment services	All frequency containment services available. Risk of saturation / depressed prices	All frequency containment services available. Risk of saturation / depressed prices	The automatic Frequency Restoration Reserve (aFRR), also known as secondary reserve, opens in the near future.
Primary response - Fast frequency response	Important line of revenue Risk of saturation	NO compensation	Primary response paid for storage Risk of saturation
Capacity mechanism	Auctions of different durations for pricing for new and existing capacity	Pending regulation. Auctions of different durations for pricing for new and existing capacity	Auctions for new ALM capacity 27 kEUR/MW/year for 7 years.
Management of technical restrictions	Congestion pricing in particular nodes. Technical restriction management market.	Congestion pricing in particular nodes. Technical restriction management market.	Congestion pricing in particular nodes. Technical restriction management market.
Virtual transmission lines - planning	Storage as an alternative to grid investments	Planning does not explicitly include storage.	Planning does not explicitly include storage.
Voltage monitoring	Market revenue per node	Pilot projects underway	Revenue not available for ALM
Local markets	Revenue from flexibility at the distribution level	Pilot projects	Revenue not available for ALM
BTM - billing	Legally enabled	Legally enabled Lack of incentives	Legally enabled Lack of incentives

Revenue/ service available	Revenue under evaluation/ pending approval	Revenue not available

	Italy	Germany
Daily market arbitrage	Opportunities are increasing as renewable penetration rises. Different pricing by region.	High opportunities due to price volatility.
Balance - frequency containment services	Capacity payments for new storage capacity: 15 years 30-50 kEUR/MW/year	All frequency containment services available. Risk of saturation / depressed prices
Primary response - Fast frequency response	FFR auctions for new storage capacity	Primary response paid for storage Risk of saturation
Capacity mechanism	Capacity payments for new storage capacity: 15 years 30-50 kEUR/MW/year	Capacity mechanism in effect
Management of technical restrictions	Congestion pricing in particular nodes. Technical restriction management market. Significant cross-border congestions between regions	Congestion pricing in particular nodes. Technical restriction management market. Significant congestions. Use of storage as an alternative to grid investments
Virtual transmission lines - planning	Planning does not explicitly include storage.	Storage as an alternative to grid investments
Voltage monitoring	Revenue not available for ALM	Revenue not available for ALM
Local markets	Revenue not available for ALM	Revenue not available for ALM
BTM - billing	Incentives for BTM storage	Grid users increasingly combine photovoltaic systems with storage to increase self-consumption driven by the low grid injection tariff.

This table looks at the different revenue lines and their availability in Australia and the California and Texas markets in the U.S.

Table 9. Comparison of U.S. and Australian Experiences: Tariff Framework and Business Models

	UNITED STATES - CALIFORNIA	UNITED STATES - TEXAS	AUSTRALIA
Daily market arbitrage: energy	Nodal pricing of energy Discharges and zero prices in nodes with high photovoltaic penetration: possibility of charging batteries at low prices. During the night, price spikes continue marking generation with gas (combined cycle). Growing opportunities for energy arbitrage.	Nodal pricing of energy Possibility of negative prices. During the night, price spikes continue marking generation with gas (combined cycle). Growing opportunities for energy arbitrage.	High opportunities for arbitrage Primary revenue line
Balance - frequency containment services	Nodal pricing Primary source of revenue of battery projects in operation	Nodal pricing Primary source of revenue of battery projects in operation Risk of cannibalization: installed battery capacity > reserve requirements	Participates in ancillary NEM services: restart, regulation of ups and downs
Primary response - Fast frequency response	Revenue available for storage Limited volume cannibalization risk	Revenue available for storage Limited volume cannibalization risk	Battery storage systems can provide fast frequency control service
Capacity payment	Capacity payments have shown a growth trend in recent years. Greater need for firm power to achieve decarbonization goals.	One of the only U.S. markets without a capacity payment.	Capacity is available to address demand requirements in peak loads.

Revenue/ service available	Revenue under evaluation/ pending approval	Revenue not available

	UNITED STATES - CALIFORNIA	UNITED STATES - TEXAS	AUSTRALIA
Management of technical restrictions Virtual transmission lines - planning	Nodal pricing of energy and reserves Nodal price signals equivalent to congestion revenue	Nodal prices act as a signal for location.	Provides additional capacity to satisfy the projected load increase for the purpose of delaying, reducing, or omitting investment in the transmission or distribution system. Significant potential given the geographical characteristics of Australia.
Voltage monitoring	No specific revenue line exists for storage.	No specific payment exists for storage.	Storage can participate locally to improve electricity quality through injection or absorption of reactive power to control irregularities.
Local markets	Different local flexibility markets under development offer business opportunities for batteries. Especially connected in distribution.	Nodal prices act as a signal for location.	Pilot projects
BTM - billing	Important in combination with photovoltaic self-consumption. Important regulatory push at the federal level to incentivize distributed resources. Important market and applications for active demand response and aggregation: potential for combining aggregation of distributed generation and BTM storage	Applied primarily to business and industrial customers	High electricity prices in Australia make this BTM installation strategy highly attractive to investors.

4

Regulatory Progress for Incorporation of Energy Storage in Latin America and the Caribbean

The growing size of intermittent renewable energy in the electricity supply industry makes the participation of storage devices increasingly valuable for maintaining a real-time balance of supply and demand at all transmission grid points or nodes. Loads that increase when real-time prices are low (storage charging) and diminish when real-time prices are high (storage discharging) can significantly contribute to maintaining the system's balance in regions with a decreasing amount of dispatchable generation capacity.

The development of storage in forms other than pumped hydro is at an incipient stage in LAC, however. There are several reasons for this:

- The first is that in all countries in the region, except for Chile and Uruguay, the percentages of intermittent renewable energy (solar and wind) did not exceed 15% of the energy produced in 2022.
- The second reason is that many countries in the region, such as Bolivia, Peru, and Argentina, have abundant gas for producing energy so prices are not so high and there aren't variations between night and day that justify storage for energy arbitrage.
- The third reason is that several countries in the region have high hydroelectric production capacity, such as in the cases of Brazil, Colombia, Costa Rica, and Ecuador, where hydroelectric production accounted for

more than 60% in 2022.[5] Hydroelectric generation produces an effect similar to that of cheap gas, with the added factor that much of it can be dammed to permit the necessary regulation and reserves for the system.

- Finally, the last reason is that most countries in the region have incomplete regulatory frameworks without obligatory markets and co-optimization in the acquisition of energy and reserves. They also have a low level of temporal granularity (Peru and Chile are the only ones in the region that have made progress on this last point) so they do not promote price signals for storage.[6]

In the case of consumers, practically all countries in the region have distribution schemes integrated with marketing and “flat” pricing for the end consumer, which does not encourage installation of BTM storage. In addition, some countries, with the exception of Chile, have set up net billing systems that inhibit storage. Given this, it comes as no surprise that storage initiatives have been limited to a few installations for spinning reserves and others for increasing firm power in accordance with each country’s capacity payment regulatory framework.

To this respect Chile has been at the forefront in the region, and the development of projects has forced it to update regulations (not the reverse). It is also the region’s most advanced country in legal and regulatory aspects. As for regulation itself, with the aforementioned exception the region’s countries have still not clarified if storage will be a new market agent or if it will be similar to one of the existing agents. No rules exist, either, for dispatching storage units that are not pumped hydro.

Accordingly, the case of Chile is described below in detail, after which several other LAC cases will be reviewed.

[5] Ember’s latest yearly electricity generation, capacity, emissions, and demand data from over 200 geographies. Yearly electricity data; updated on 12 September 2023.

[6] Wolak, Inostroza, Di Avante et al. (2020). “Ancillary Services in Peru”. https://www.coes.org.pe/Portal/Publicaciones/Informes/.

4.1 Chile

The Chilean market has been at the forefront globally in the development of applications with BESSs, totaling 52 MW installed in three thermoelectric plants for energy generation in the model of release of spinning reserve capacity for primary frequency regulation, the goal being to offer it to the system as energy and in replacing it the BESS system provides primary frequency regulation. This was particularly useful in 2009-2010 when Chile was having high energy costs due to gas cutoffs from Argentina and the high price of oil. The installation of 12 MW in BESSs in 2009 helped reduce diesel generation and increase coal generation at much lower variable costs, maintaining service quality with respect to RPF. Estimates for that time figured some US $60 million in savings on system costs.

This equipment was installed according to the regulations of that time by modifying a technical procedure of the Economic Load Dispatch Center of the Big North Interconnected System (CDEC-SING) (currently the coordinator). This was not without controversy and had to be settled by the Chilean Panel of Experts, which in its Opinion 3-2009 of 2009 ruled against the CDEC-SING and agreed with the company driving the project, giving rise to the CDEC-SING's procedure for treatment of BESS-type devices that permitted release of the thermal unit for producing energy and allowed the BESS to provide the spinning reserve. An important feature of this procedure is that it permitted tying of the BESS to the thermal unit without the need for the BESS to be BTM. Indeed, as can be seen in the figure, it was installed more than 300 km away from the thermal plant that released its energy production capacity. This is highly relevant because it recognizes that the BESS can be installed at more efficient grid points and still be tied to a thermal plant located at another point.

Under this regulation, 40 MW more of BESS were installed under the indicated modality, "tied" to a thermal machine but not necessarily BTM.

Later, Law 20936 of July 20, 2016 incorporated the concept of storage as a new coordinated agent. Once again, Chile has been a pioneer, since this concept is recently being adopted in Europe and the U.S.

The “Regulation of Ancillary Services”[7] and the “Regulation of Coordination and Operation of the National Power System”,[8] both published during 2019, already describe the participation of storage systems in ancillary systems, such as transmission facilities with energy arbitrage, defining the mechanism for participation of the storage system in dispatch.

Additionally, on November 21, 2022, the Storage Act was published which grants recognition to this technology as a new market player, different from a generator, transmitter, or distributor. The regulations to this law are still in the process of preparation. The first of these, a modification of the regulation for power transfers, recognizes storage as firm power, both stand-alone and as part of a renewable installation (solar or wind), in hybrid format as well as tied.

Currently under construction is a single-inverter hybrid solar-plus-storage project with an output of 112 MW and solar capacity of 180 MW. In addition, a 10 MW pilot project called a “virtual dam” has gone into operation. This project will help increase the firm power recognized for a run-of-the-river hydroelectric plant in the system.

Several other projects are at different stages of development, but the application of arbitrage has yet to pass its break-even point. Moreover, some announced changes in the regulation, including potential “storage bidding” (not very efficient but widely used in other countries where there are no proper market signals for storage installation, as will be seen further below), have halted the development of these projects as they await the final results of the proposed changes.

4.2 Colombia

A typical example of what was mentioned above is the project developed on the Colombian coast consisting of the design and installation, purchase of supplies, construction, commissioning, operation, and maintenance of an ESS using lithium-ion batteries (BESS) for the purpose of mitigating problems of transmission grid insufficiency or failure in the regional

7 Reglamento de Servicios Complementarios. Chile. Decree 113 27-MAR-2019 MINISTERIO DE ENERGÍA - Chilean Law - Library of the National Congress (bcn.cl).

8 Reglamento de la coordinación y operación del Sistema Eléctrico Nacional (Chile). Decree 125 20-DIC-2019 MINISTERIO DE ENERGÍA - Chilean Law - Library of the National Congress (bcn.cl).

transmission system (RTS) and local distribution system (LDS). With a system delivery capacity of 45MW/45MWh and a delivery duration of one hour, this project enables the grid to operate under an N-1 contingency with the failure of one of the Atlantic RTS grid units.[9]

Since Colombia has a single-price market that does not recognize congestions in stock market prices and therefore does not produce signals for reducing congestions, Colombian regulation (CREG Resolution 098 of 2019) has sought to incorporate BESSs to prevent congestion problems in the national transmission system (NTS) and RTSs, a forced solution since it has no efficient price signals in its model.

With regard to the allocation mechanism, a centralized process was designed whereby the sector planning body, the Mining and Energy Planning Unit (UPME), identifies the location of the installation point and voltage level for system connection (in this case it was selected at 34.5 KV in the El Silencio substation). Once the scope of the system was defined, the unit issued a call for bids to assign a project developer and operator. UPME selected the project investor and builder through the UPME RTS Public Tender 01 of 2021. Ten companies submitted bids and the project was awarded to the Canadian Solar firm.[10]

In the case of RTS and LDS BESSs the regulation requires the specific need to be identified in order to provide the defined services (congestion in the case of the Atlantic project). In the LDS case, taking into account that the BESSs can provide a variety of services, each grid operator can define battery installation according to the specific requirements and compensation for the assets is through payment for the distribution activity. (UKPACT-Colombia, 2020).

Table 10 below shows a comparative summary of the current market schemes that would permit the incorporation of some ESS applications in Colombia and Chile.

[9] UPME. (2021). Appendix 1 UPME RTS Public Request for Proposals 01 of 2021. Bogota.
[10] UPME, Press Release 004 of 2021 2021.

Table 3. Summary of the Current Regulatory Status in Chile and Colombia

Market / Revenue	Application	Chile	Colombia
Wholesale market	Electric energy time shift (arbitrage)	Minimum cost pool dispatch (cost-based) Optimization of ESS energy assignment Only term financial markets Nodal marginal pricing Low granularity Installed capacity of 112 MW, hybrid photovoltaic system, 5 hours	Single price - "feasible dispatch" Regulated settlement prices for redispatch Low granularity
	Capacity market	Explicit capacity payments Clear definition of peak hours	NO capacity payments
	Virtual dam	Explicit capacity payments 10 MW of installed capacity, 5 hours	NO capacity payments
Ancillary services - Frequency containment	Spinning reserve, other reserves and supplements, inertia emulation	Impractical co-optimization of the acquisition of ancillary energy and frequency control services. Only term financial markets Nodal marginal pricing Low granularity Stamp allocation. Installation capacity of 52 MW, 1 hour, to release thermal capacity during the gas crisis	Contracting of ancillary services of sequential energy and frequency control. Single price. Low granularity Stamp costs.
Voltage regulation	Voltage support	Acquisition through long-term auctions Obligatory at regulated cost in uncompetitive situations. Defines services and lets technologies compete to provide them.	Obligatory without compensation.

Market / Revenue	Application	Chile	Colombia
Recovery systems	Black Start	Acquisition through long-term auctions Obligatory at regulated cost in uncompetitive situations. Defines services and lets technologies compete to provide them. Nodal marginal pricing	Single price Optional
Transmission grid services	Postponement of transmission investments	Optimum transmission expansion plan. Acquisition through long-term auctions.	Current installation of 30 MW in the coastal area, special rule defined by CREG.
	Management of congestions and technical transmission restrictions	Minimum cost pool dispatch (cost-based) Nodal marginal pricing Low granularity Optimum transmission expansion plan.	Single price - "feasible dispatch" Regulated settlement prices for redispatch Low granularity
Distribution grid services	Postponement of distribution update.	Optimum distribution expansion plan. Efficient tariffs.	Marketing companies
End customer rate management - Energy Management Systems	Peak shaving. Supply quality. Supply security. Demand management. Self-consumption optimization	Limited availability of smart meters. Net-metering. Retail integrated in the distribution monopoly	Limited availability of smart meters. Net billing
Off-grid solutions	Mini-grids: system stability services	Limited availability of smart meters Net metering.	Limited availability of smart meters

4.3 Brazil: First Regulatory Steps

Regulatory initiatives for storage are still incipient in Brazil. The approach is highly focused on supporting distributed generation based on renewable sources. Notably, regulatory developments are linked to the importance of storage for providing access to energy in isolated areas of the Amazon.

Law 14.300 of 2022 establishes that distributed photovoltaic micro- and mini-generation can be dispatchable if it has batteries with a modulation capacity of at least 20% of the monthly generation capacity of the generating plant and is dispatched by a local or remote controller.

Regulatory Resolution 1.009 of 2022 of the National Electrical Energy Agency (ANEEL, its acronym in Spanish) allows for storage systems to be included in the notices of contracting of distributed generation by the distributor. The condition for contracting is for it to provide an alternative to traditional grid investments or improve the quality indicators of the service/product.

ANEEL's Regulatory Resolution 1.016 of 2022 provides that after a generating plant is awarded, contracted, and installed by means of auction in isolated systems, the seller may replace generating units with non-renewable sources in the plant with renewable units with storage, provided the respective public notice conditions, contracted product, and minimum amounts of power and energy are assured.

ANEEL also prepared two subsidies (TS 11/2020 and TS 11/2021) aimed at including the vision of sector agents on storage and distributed energy resources, respectively. During TS 11/2021 the agents unanimously asked for preparation of a regulatory framework for storage. Technical Note 137/2022 of TS 11/2020 presented a proposed roadmap for development of regulations for the different topics and subtopics of electrical energy storage (see Table 11).

Table 11. Draft Roadmap for Development of the Regulatory Framework in Brazil by ANEEL

Source: Technical Note 137 /2022-SRG/ANEEL.

1st Cycle 2023 and 1st semester of 2024	Storage, except reversible hydropower plants: • Concept: Specifications and characteristics; • Granting of authorization: Storage together with the generator, stand-alone storage, cases of exemption from authorization; • Grid access and use: Tariffs, supervision and control system, and protections; • Access to marketing: Registration, measurement, and accounting and settlement aspects; and • Adjustments to eliminate regulatory barriers: Ancillary systems, capacity auctions, demand response, and isolated system auctions.
2nd Cycle 2nd semester of 2024 and 2025	• Final adjustments to grid procedures and marketing rules; • Regulatory sandbox evaluation (pilot projects); and • Reversible hydropower plant: Study of inventory and optimum use problems.
3rd Cycle 2026 and 2nd semester of 2027	• Final adjustments to the instructions for reversible hydropower plants in matters of grid procedures and marketing rules. New business models: • Reduction of curtailment and constrained-off; • Definitions of value stacking; • Aggregators of related services; and • Computer model simulation: impacts on operational scheduling and short-term price formation.

ANEEL plans to open a public consultation to discuss storage regulation at the end of this year.

In 2020, the federal government created a program in the north of the country aimed at serving the low-income population in remote regions of the Legal Amazon states.[11] The program is an extension of the "Luz para Todos" ("Light for All") program created in 2003 to help rural families lacking access to public electricity services by expanding the grid.

[11] Legal Amazon Legal is an area covering nine Brazilian states in the Amazon basin. Established by the federal government through Law 1.806/1953, it brings together regions with identical characteristics to improve planning for the Amazon region's social and economic development. The Legal Amazon currently covers all the states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima, and Tocantins and part of the state of Maranhão.

The "Maiz Luz" ("More Light") program envisages the use of renewable sources of electricity generation and includes the possibility of using storage to replace diesel- or gasoline-fueled generation in off-grid communities, this being valid until the end of 2030. Some 90% of the resources come from the Energy Development Account while 10% are from the distributor.[12] The second Maiz Luz work program, approved for Legal Amazon on October 25, 2021, will provide service to 4,380 households with the installation of 17,520 photovoltaic panels, 8,760 LiFePO4 (lithium iron phosphate) batteries, 4,380 controllers/inverters, and an anticipated investment of R$ 209.65 million.[13]

4.4 Storage Applications that Have Not Required Regulatory Adjustments for Implementation

Some experiences in the region show that not all ESS applications require regulatory adjustments, particularly those installed BTM. These proposals have arisen at the initiative of agents looking for greater operational efficiency. This is the case of the spinning reserve of thermal plants, which thanks to the incorporation of ESSs keeps the plant from having to vary the machine power and allows it to continue operating within the most efficient range, in addition to reducing the opportunity costs of idle generator capacity. Examples of this application are the 7 MW Termozipa Plant in Colombia,[14] the 10 MW each Andrés and DPP plants in the Dominican Republic,[15] and the 14.6 MW Ventanilla plant in Peru,[16] which without an enabling regulatory framework for storage have been able to incorporate ESSs. The foregoing suggests that not all storage applications need to be regulated and that regulatory adjustments should be focused on eliminating existing barriers under market rules that promote the free participation of storage.

[12] Sectoral charge designed to develop energy resources, increase competitiveness among sources, and subsidize access to the grid for low-income users. This charge is collected by distributors and paid by users.

[13] https://opovoamazonense.com.br/comunidade-de-manacapuru-beneficiada-com-energia-solar/

[14] Enel-Emgesa inaugura el primer sistema de baterías de almacenamiento de energía de Colombia

[15] Benjamin-Villalobos-Almacenamiento-de-Energia-y-Sistemas-Integrados.-AES-Dominicana.pdf (adie.org.do)

[16] Enel Perú inauguró BESS Ventanilla: primer sistema de baterías de gran capacidad del país - enel.pe

4.5 Regulatory Summary for Energy Storage in LAC

As we have seen in the previous sections, despite not having fully developed regulatory and business frameworks for ESSs and their applications, LAC countries have been making regulatory adjustments to regulate the arbitrage, complementarity, and transmission quality services offered by ESSs. Table 12 summarizes the main regulatory measures taken for ESSs in Brazil, Chile, Colombia, Mexico, and the Dominican Republic. The table includes direct references to facilitate consultation of the regulatory measures.

Table 12. Regulatory Summary for Energy Storage in LAC

	Dominican Republic	Colombia	Brazil
Application	Arbitrage	Transmission - service quality	Arbitrage in distributed generation
Scope	Requirements for battery ESSs tied to variable renewable energy generation projects	Battery ESSs to mitigate transmission grid insufficiency or failure problems	Possibility of incorporating ESSs in micro and mini DG and isolated systems
Description	Defines storage capacity according to the generation capacity of the renewable power plant. < 50 MWac, will not be required => 50 MWac to 100 MWac, 30% of their capacity, 4 hours > 100 MWac to 200 MWac, 50% of their capacity and 4 hours > 200 MWac, will require prior CNE evaluation	ESSs considered a transmission asset, compensation by means of annual expected revenue that includes CapEx and OpEx during the entire service time.	Distributed photovoltaic micro- and mini-generation can be dispatchable if it has batteries with a modulation capacity of at least 20% of the monthly capacity. DG contracted by distributors can include ESSs.
Regulation	CNE-AD-0004-2023	CREG 98 OF 2019 CREG 101-023 OF 2022	Law 14.300 of 2022 ANEEL Regulatory Resolution 1.009 of 2022 ANEEL Regulatory Resolution 1.016 of 2022
Link	https://www.cne.gob.do/inicio/sobre-nosotros/marco-legal	Alejandría - Resolución 98 de 2019 CREG	Base Legislação da Presidência da República - Lei nº 14.300 de 06 de janeiro de 2022 RESOLUÇÃO NORMATIVA ANEEL Nº 1.016, DE 19 DE ABRIL DE 2022 - RESOLUÇÃO NORMATIVA ANEEL Nº 1.016, DE 19 DE ABRIL DE 2022 - DOU - Imprensa Nacional (in.gov.br) RESOLUÇÃO NORMATIVA ANEEL Nº 1.009, DE 22 DE MARÇO DE 2022 - RESOLUÇÃO NORMATIVA ANEEL Nº 1.009, DE 22 DE MARÇO DE 2022 - DOU - Imprensa Nacional (in.gov.br)

	Chile	Mexico	Barbados
	Ancillary services Arbitrage Transmission	Arbitrage	Pilot projects
	ESS as a new agent. Enabling of ESSs for providing different services, with respective compensation	ESSs are considered as generation and are represented in the market by a generator agent that makes the same transactions as a regular generator agent.	Establishes the tariffs applicable to pilot projects for the purpose of collecting information on the systems' operation. The projects.
	Ancillary Services Regulation (2019). ESSs enabled to provide ancillary services. Stack ESS revenue from ancillary services with arbitrage revenue. ESSs that provide ancillary services will not participate in energy transfer balances due to their injections and withdrawals – Energy withdrawals made by ESSs for ancillary services will not be subject to the associated charges for end customers.	ESSs must register as power plants and be represented by a generator in order to operate storage equipment. These generators may make all purchase offers corresponding to load centers.	The energy storage and tariff framework sets the tariffs applicable to pilot projects in a four-year period for up to 50 MW. The systems must provide the grid with three or more storage services and two or more voltage or reactive power services. The projects will apply for a storage license from the Ministry of Energy and Business and be eligible to receive the associated tariff for ten years.
			FTCUR/DECEST/2023-03.
		https://www.cenace.gob.mx/Docs/14_REGLAS/Bases/Bases%20del%20Mercado%20El%C3%A9ctrico%20[DOF%2008-09-15]%20.pdf	2023-06-28_commission_decision_EST.pdf (ftc.gov.bb)


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Conclusions: Lessons Learned

This document reviewed the basic elements of the regulatory framework for storage incorporation and its implications for business model viability. By evaluating different international experiences and regulatory approaches we have been able to identify the main regulatory challenges and barriers as well as the best practices implemented to overcome them.

Energy storage is a key pillar of decarbonization and sustainability of the entire power and energy system. Consequently, **investments in storage systems show the highest rate of growth of all technologies that contribute to decarbonization.** Different technologies exist for storing energy. They all have potential applications and different levels of technological maturity. Of all technologies, **electrochemical (battery) storage has the strongest potential for facilitating the integration of renewables into power systems, taking into account the level of maturity and its technical applications.**

The deployment of storage is necessary for efficient integration of renewable generation. But this deployment requires the combined efforts of many sector agents, from legislators to storage project promoters, as well as an enabling regulatory framework. **In this report we have analyzed the minimum requirements of an enabling regulatory framework for the development of storage projects.** Any regulatory framework should be focused on eliminating project development barriers and providing adequate incentives to optimize storage deployment.

The countries reviewed as having best practices include **Europe (United Kingdom, Spain, France, Italy, and Germany), United States (CAISO in California and ERCOT in Texas), and Australia.** Two criteria were used in the selection of best practices: 1) level of storage market maturity (experience in operational storage applications and projects); and 2) level of regulatory development. **In some jurisdictions such as California (U.S.) storage project development has preceded regulation, while other countries (European Union) have benefitted from international experience for defining regulatory frameworks based on success cases such as that of the United Kingdom.**

The regulatory framework for storage should define at least the following aspects:

- **Definition and treatment of storage.** Most of the analyzed best practices define storage explicitly as a liberalized activity.

- **Grid access and connection conditions.** Some systems consider storage a generator while others give it a specific treatment.

- **Project permits and authorization.** Most legislators authorize storage the same way they authorize generation projects.

- **Grid fees and charges.** International experiences differ on this point. In some countries such as Spain storage is exempt from paying grid fees. In others it pays fees as a consumer or producer (U.S. and France), and in still others such as Germany it pays for charging and discharging.

- **Market participation.** Best regulatory practices aim at full market opening (energy, capacity, frequency control services, etc.) for storage, which should compete in a non-discriminatory manner with other agents.

- **Tariff framework.** The best international experience indicates that the optimum tariff framework for both the system and the storage promoter is one that compensates the services storage provides according to the system's needs.

In relation to this last point, in this report we have analyzed in detail the business model options based on revenue stacking that exist in each market. **The concept of revenue stacking defines the possibility of stacking different revenue sources to make the storage investment commercially viable.** The storage tariff framework conditions the business model.

Our analysis of international experiences identified the following revenue lines as essential for storage to cover its investment and operating costs:

- **Energy arbitrage.** In all the analyzed countries storage is charged during low-price moments in the wholesale energy market (i.e., excess of renewables) and is charged [sic] during price peaks.

- **Capacity mechanism.** Capacity payments are key revenue for giving **long-term certainty to the promoter and remunerating the contribution of storage to supply security.** In several of the analyzed experiences (California, Italy, United Kingdom, and France) the assignment of a long-term guaranteed capacity payment facilitated deployment of the storage.

- **Balance - frequency containment services.** Battery modularity and fast response (to ups and downs) makes them a competitive agent for providing frequency control services to system operators. **Together with arbitrage, this is the main application of batteries in the world's commercial business models.**

In addition to these revenues, other systems also compensate for reactive power, congestion prices, and fast frequency response at the grid level.

Finally, the potential of BTM storage should be noted. **BTM storage has potential for reducing end consumer electricity bills, permitting optimized consumption and active demand management.** International experience shows that BTM storage development is contingent upon 1) the use and development of self-consumption and distributed generation, and 2) the tariff scheme (hourly discrimination, dynamic price signals, tariffs for injection of self-consumption surpluses, and the importance of grid fees).

These lessons learned will be used in later phases of the project to make recommendations on the updating of each jurisdiction's regulatory framework and the business models they should incentivize.

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