3. Barriers and Enablers for Implementation of Storage Technologies

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This report is part of the study:
Technology Roadmap and Mitigation Potential of Utility-scale Electricity Storage in Mexico

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Executive Summary

The deployment of energy storage systems can potentially offer an array of benefits. If the value of those benefits (market, environmental, socioeconomic, technical, etc.) surpasses concomitant costs, then it might be worthwhile to consider implementation of storage in the electric system. While this section does not compare benefits to costs, it does identify the barriers and enablers to storage implementation -should implementation be desirable-, which presently exist in Mexico. Since no enablers were identified, the discussion is focused on barriers found in the electricity sector's regulatory framework.

The key barriers identified by the working group participants from the public and private sectors were:

- Lack of a market for fast frequency response, the principal way for storage systems to participate in energy markets around the world, even though frequency control provided by reserves is remunerated.
- The absence of a formal procedure for procurement of ancillary services not included in the wholesale market excludes storage systems from offering those services.
- Lack of long-term contractual framework for services offered by storage, which could reduce risk of long-term-investment.

Additional regulatory shortcomings worth mentioning:

- Classifying storage as generation presents various challenges, such as:
    - Paying transmission tariff twice. As a generator, storage pays transmission tariff for injecting the energy into the grid, which is meant to cover 30% of transmission costs. Storage is also required to pay a transmission tariff when it is charging, a tariff paid by the load, which is meant to cover 70% of the cost of transmission.
    - Classifying storage as generation forces storage technologies to compete on equal footing with conventional generation, which it cannot do for numerous services because of the limited time energy can be released.
- Lack of technical norms and standards, as well as environmental regulations related to storage.
- Lack of fiscal incentives akin to those afforded to renewable generation.
- More stringent requirements than conventional generation to receive availability payments in capacity market. Whereas storage is required to provide electricity for 6 hours at full capacity, the conventional generation is required to provide it for only 3 hours.
- Long-term generation capacity auctions do not recognize energy supply limitations faced by storage. Consequently, although storage is classified as generation, it cannot compete with conventional generation.

In response to the aforementioned barriers, the participants of electricity storage workgroups suggested solutions, which were generally the inverse of the stated barriers. For example, if an identified barrier was "undefined process for provision of ancillary services", the proposed mitigant was "defining a process for provision of ancillary services", etc. Another fragment of

responses suggested monetizing benefits to the grid, investigating in more detail potential benefits of storage through pilot projects, promoting storage education at universities, etc.

Potential removal of barriers to storage participation could permit four prototype modalities for storage to participate in the electrical system. Although all storage technologies potentially offer positive externalities, such as mitigation of greenhouse gases, increased energy independence, decrease in peak electricity prices, etc., each modality of participation in the electrical system presents a different set of costs and benefits to both storage investors and society as a whole. Whereas the chapter lists numerous costs and benefits associated with each mode of market participation, here only key costs and benefits are presented for each modality.

Table 1. Implementing option under current regulations- advantages and disadvantages.

Option	Benefits/ Disadvantages	Investors (CFE & IPPs)	Society
Market-Driven Standalone Storage	Benefits	Investor controls and administers the asset as she sees fit (if it is under 20 MW capacity).	Decline in GHG emissions and decline in power prices due to peak shaving and decreased congestion.
	Disadvantages	Investor pays double transmission tariff.	Possible environmental impacts, conditional on the type and the use of storage technology.
Market-Driven Associated Storage	Benefits	Investor pays only generator's transmission tariff	Decline in GHG emissions and decline in power prices due to peak shaving and decreased congestion.
	Disadvantages	Significant long-term capital investment without security of a long-term contract	Possible environmental impacts, conditional on the type and the use of storage technology.

Option	Benefits/ Disadvantages	Investors (CFE & IPPs)	Society
Standalone Storage, Classified as Transmission	Benefits	Security of a long-term contract and no market risk	Previously mentioned benefits to society can be optimized, because decisions are not market-based

Option	Benefits/ Disadvantages	Investors (CFE & IPPs)	Society
& Controlled by CENACE	Disadvantages	Investor operates, but doesn't control the asset	Long-term contract might make it difficult for CENACE to take advantage of the latest technology
Associated Storage, Controlled by CENACE	Benefits	Security of a long-term contract and no market risk	Previously mentioned benefits to society can be optimized, because decisions are not market-based
	Disadvantages	There might be a conflict between the operation of the plant and the operation of storage, since both interconnected on the same premises.	Long-term contract might make it difficult for CENACE to take advantage of the latest technology

Note. IPP: Independent Power Producer

Arguably, there might also be certain drawbacks associated with a contractual storage arrangement. For example, a long-term contract might make it difficult for CENACE to take advantage of latest storage technologies which enter the market, and which might be cheaper and more efficient.

It is also worthwhile mentioning that in some markets around the world, such as in Denmark, storage is classified as storage and not as generation. Creating a new market participant category eliminates numerous challenges associated with classifying storage as generation. The rest of Europe is reviewing the Danish treatment of storage, and is likely to follow suit.

1. Introduction

There are many options in the electricity sector to mitigate generation of greenhouse gases (GHG). Examples include renewable energy, electricity storage, demand control, or distributed generation just to name a few. This study focuses on electricity storage, and does not compare it to other options for mitigating GHG or enabling a high share of variable renewable energy. It does however, compare in section 5 the costs and benefits of electricity storage to no storage or the status quo.

The costs and benefits of electricity storage are considered from a social point of view. If there is an indication that the benefits surpass the costs, then from a social perspective electricity storage might be worthwhile considering. To that end, it is important to have a regulatory framework that does not hinder implementation of storage technologies by either the public or private sectors.

This section considers the existing Mexican regulatory framework as it pertains to energy storage, the existing barriers to storage implementation, and suggestions as to how to modify regulation to foster storage.

2. Description of the Electricity Storage Market, Regulatory and Financial Framework in Mexico

Before reviewing Mexican laws and regulations relevant to energy storage, it is important to identify the hierarchy of those laws to understand their respective impact on the energy market. Specifically, the discussion regarding possible modifications to the regulatory framework in a latter portion of this chapter is cognizant of the fact that a law or regulation cannot contradict laws and regulations preceding it on the hierarchy scale, which is as follows:

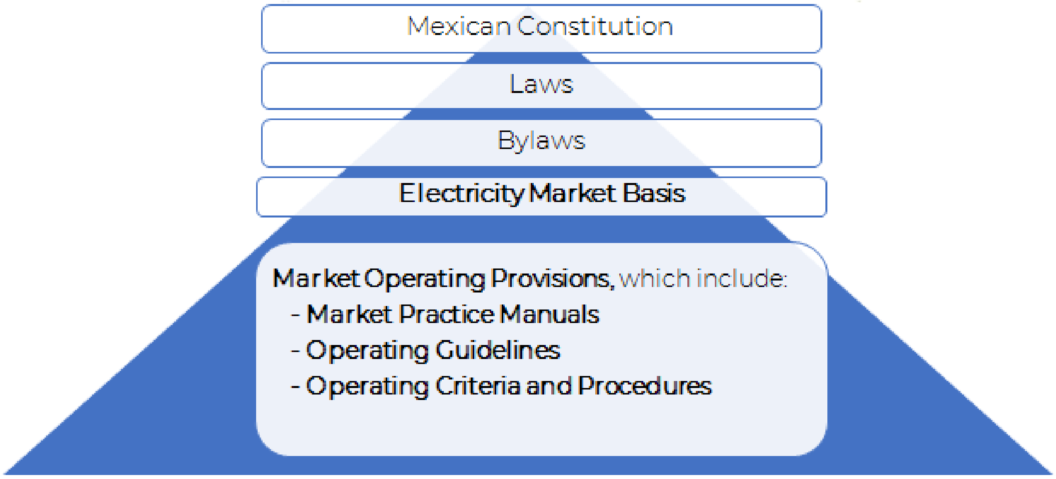

Figure 2.1. Legal hierarchy affecting the Mexican electricity storage market. Source: own elaboration.

The order in which the laws and regulations were modified and/or created to facilitate the energy reform indicates their hierarchy, with most important laws being modified first. The chronology of the energy reform regulatory framework follows:

- 2013: Constitutional reform to permit private sector participation in the electricity market (Congreso de la Unión, 2013). The reform creates an electricity market. Transmission and distribution remain under state control.
- 2014: The Electricity Industry Law (*Ley de la Industria Eléctrica*) is published by the Mexican Congress (Congreso de la Unión, 2014). It outlines how the electricity market will work, and defines the roles of market participants, the system operator, the government and the regulator.
- 2015: The Energy Transition Law (*Ley de Transición Energética*) is published by the Mexican Congress (Congreso de la Unión, 2015). The law regulates the transition towards increased use of renewable energy.
- 2015: The Electricity Market Basis (*Bases del Mercado Eléctrico*) are published by the Energy Secretariat (SENER, 2015). The Electricity Market Basis is at the top of the hierarchy of documents that together comprise the Electricity Market Rules, followed by the Operating Market Provisions. The section 1.5.1 of the Electricity Market Basis, details further the regulatory hierarchy of documents that comprise the Operating Market Provisions.
- Market Practice Manuals[1] (SENER, 2016-2019) (Manuales de Prácticas de Mercado). The manuals and what follows detail market operations.
- Operating Guidelines (Guías Operativas).
- Criteria and Operating Procedures (Criterios y Procedimientos de Operación).

While the first version of the Electric Market Rules (Electricity Market Basis and Operating Market Provisions) were published by the Energy Secretariat, all subsequent versions and

[1] The manuals have been published at different times, but all of them can be found on the system operator's website: https://www.cenace.gob.mx/Paginas/Publicas/MercadoOperacion/ManualesMercado.aspx

updates are to be published by the Energy Regulatory Commission (CRE, for its acronym in Spanish) (SENER, 2015[2]).

The legal hierarchy also contains bylaws. Unlike laws that are a product of a legislative branch, the executive branch of the government produces bylaws. There are three kinds of bylaws in this matter for different purposes: (i.) to regulate the relation between (permits) the market participants and the regulating institutions, for example the LIE bylaw (ii.) to set planning rules for the electric system as LTE Bylaw and (iii.) to regulate the organization and operation of involved institutions as for example the CENACE, SENER or CRE organization bylaws, these ones set the rules not so much for the electricity market, as for the entities regulating the market.

In summary, the principal law guiding the electricity industry is the Electricity Industry Law (LIE), and the principal regulation are the Market Basis., and the Market Practice Manuals.

2.1 Existing Legal Framework with regard to Electricity Storage

The direct mention of energy storage in the existing legal framework is limited, although there are aspects of the law that can be interpreted as addressing energy storage indirectly. For example, the LIE does not mention energy storage, but LIE's Article 12, fraction XXXVII states that the CRE is responsible for "issuing and applying the necessary regulation pertinent to efficiency, quality, reliability, continuity, safety and sustainability of the national electric system" (Congreso de la Unión, 2014).

While the LIE does not mention electricity storage directly, it does define participants of the Mexican electric market, which can only be classified as one of the following: Generator, Marketer, Supplier, Qualified User, or a Non-supplying Marketer (Congreso de la Unión, 2014[3]). Consequently, in order for energy storage to participate in the electric market, it needs to assume one of those classifications.

What follows is a review of current laws and regulations, which directly addresses energy storage.

2.2 The Energy Transition Law

The purpose of the Energy Transition Law (Congreso de la Unión, 2015), according to its first article, is to regulate the sustainable use of energy and comply with obligations in terms of Clean Energies and the reduction of polluting emissions in the Electricity Industry, while maintaining the competitiveness of economically productive sectors.

[2] Section 1.5.5

[3] Artículo 3, XXVIII

The Article 38 asserts that the Intelligent Electrical Networks Program shall identify, evaluate, design, establish and implement strategies, actions and projects in the field of electrical networks, among which the following may be considered:

> (Article 38), fraction IX: The development and integration of advanced technologies for the storage of electricity and technologies to meet demand during peak hours.

The Article 79, fraction I, states that the goal of the National Electricity and Clean Energy Institute is to coordinate and carry out scientific or technological research studies and projects with academic, public or private, national or foreign research institutions in the field of energy, electric power, clean energy, renewable energy, energy efficiency, pollution generated by the electric industry, sustainability, energy transmission, distribution and storage systems, and systems associated with system operations.

2.2.1 Regulations: Administrative Provisions of a General Nature

The Electricity Market Basis 3.3.21 (SENER, 2015) states that "electrical energy storage equipment must be registered as a Power Plant and must be represented by a Generator, observing the following:

a) These Generators may make bids for the sale of all the products that the storage equipment is capable of producing, on equal terms as any other Power Plant Unit.

b) Likewise, in order to operate the storage equipment, these Generators will be able to make all the purchase offers corresponding to the Load Centers, assuming for this purpose all the responsibilities that correspond to the Load Responsible Entities.

c) When a storage equipment is part of the National Transmission Network or the General Distribution Networks, a strict legal separation must be observed between the Generator that represents the equipment in the Wholesale Electricity Market and the Carrier or Distributor that uses the equipment to provide the Public Transmission and Distribution Service, in the terms defined by the Secretary of Energy. Likewise, these Generators, Carriers and Distributors will be subject to the tariff regulation established by the CRE."

In summary, the regulation states that storage shall be classified as generation.

It is also worthwhile to mention section 6.5.1 of the Electricity Market Basis, which defines "Limited Energy Resources". Although the section 6.5.1 does not specifically mention energy storage, the subsection 4.2.8 of the Opportunity Cost Manual (described below) identifies energy storage as a Limited Energy Resource for the purpose of modelling unit allocation by the system operator, CENACE. Specifically, the section 6.5.1 states:

"6.5.1 Limited energy resources include the following:

a) Hydroelectric units with reservoir, whose characteristics will be defined in the applicable Market Practices Manual.

b) Thermal units with periodic emission limits, according to the applicable Market Practices Manual.

c) Thermal units with periodic limits of fuel availability or consumption of permitted fuel, according to the applicable Market Practices Manual.

d) Guaranteed Controllable Demand resources with contractual limits for interrupted energy may be included in the SECOND STAGE of the implementation of the wholesale electricity market. "

2.2.2 Market Practice Manuals

Opportunity Cost Manual (SENER, 2017)

In the first chapter, subsection 1.3.13, the manual defines energy storage equipment (which shall be registered as a power plant) as a "system capable of storing a specific amount of energy to release it when required in the form of electrical energy. These systems include, among others[4], pumped hydro stations, power stations that operate on compressed air stored in caverns or in some other medium, electrochemical batteries, and power plants that operate on the basis of hydrogen storage or synthetic gas that is produced from hydrolysis of water, using surplus energy from renewable sources of energy."

Subsection 2.4.1: The system operator, CENACE[5], "shall classify the energy storage equipment as a limited energy resource[6], if the following criteria are met:

In the National Interconnected System, Energy Storage Equipment with a capacity greater than or equal to 20 MW, and storage capacity greater than or equal to 80 MWh.

In Baja California and Baja California Sur, Energy Storage Equipment with capacity greater than or equal to 10 MW, and storage capacity greater than or equal to 40 MWh."

Subsection 2.4.2: "The CENACE will establish an Operational Guide[7] which will indicate how energy storage equipment will be represented in the short-term energy market optimization models. The Guide should address the following aspects:

a) Parameters related to capacity, operating limits and efficiencies of the loading and unloading cycles;
b) Parameters related to the offers of energy products and related services in the day-ahead market (MDA, for its acronym in Spanish);
c) Decision variables;
d) Restrictions on products offered during loading;
e) Restrictions on the products offered during the download;
f) Restrictions on products offered when neither charging or discharging is taking place;
g) Stored energy limits;
h) Restrictions on modes of stoppage, loading and unloading; and,
i) Transition costs between modes".

[4] This is an indicative but not exhaustive list of relevant technologies.

[5] The Mexican System Operator is referred to as CENACE (Centro Nacional de Control de Energía).

[6] Limited Energy Resource, according to Market Basis 6.5.1, refer to "hydro generation with limited water storage, thermal generation with periodic emission restrictions, thermal generation with limited access to fuel, and (in the second stage of electricity market implementation) guaranteed controllable demand "

[7] At the time of writing the Operational Guide was still not published.

The diagram below puts the short-term energy market referred to in Subsection 2.4.2 in the context of the wholesale energy market (MEM):

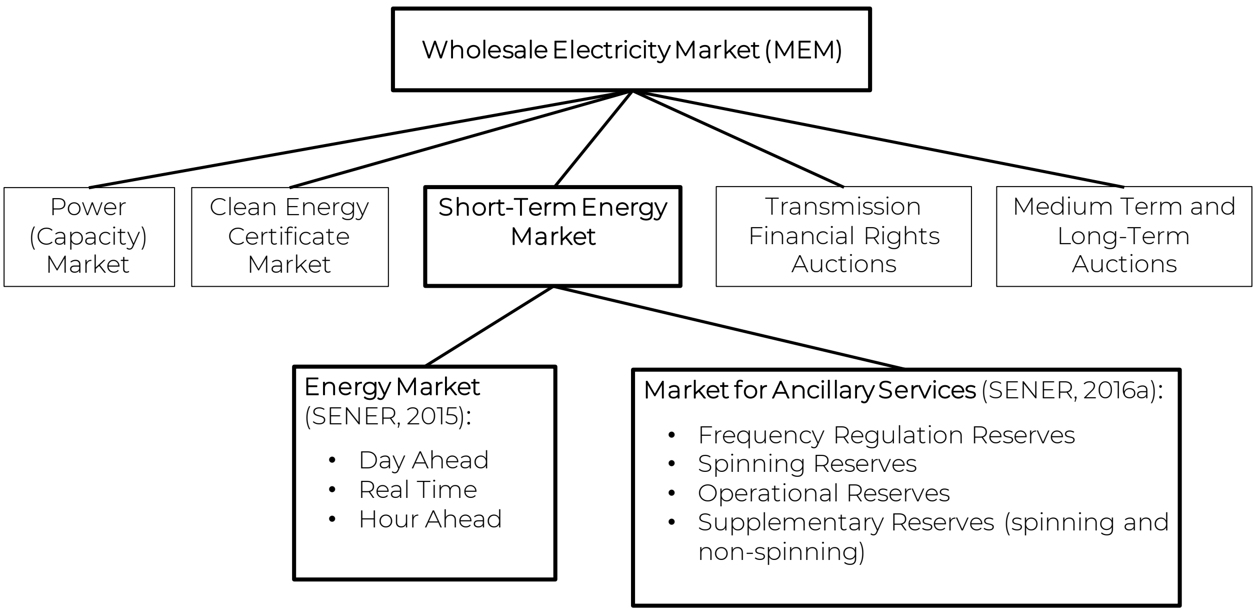

Figure 2.2. Composition of the Mexican Wholesale Energy Market. Source: own elaboration

<u>Subsection 2.4.3</u>: "The Market Participant representing energy storage equipment that is not classified as a Limited Energy Resource must present its sales offers directly in the Short-Term Energy Market, like any other Power Plant Unit, in accordance with the Short-Term Energy Market Manual.

Table 2.1. Classification of Energy Storage Equipment (source: Opportunity Cost Manual).

Energy Storage Equipment	Limited Energy Resource	Rationale	Participation Type
Equipment that cannot be optimized (or dispatched by CENACE)	No	The market participant schedules the loading and unloading cycles	Not dispatchable by CENACE
Storage with a capacity of 10MW or more, capable of providing 40MWh of electric power in Baja California (BCA) and Baja California Sur (BCS)	Yes	Energy Storage in BCA and BCS	Dispatchable, based on opportunity cost
Storage with a capacity of 20MW or more, capable of providing 80MWh of electric power into the National Interconnected System (SIN, for its acronym in Spanish)	Yes	Energy Storage installed in SIN	Dispatchable, based on opportunity cost"

Subsection 4.2.8: "The CENACE must model the limitations associated with Limited Energy Resources in the AU-CHT model[8] (CENACE's unit allocation model). The Limited Energy Resources include hydroelectric power plant units with Reservoir, the thermal power unit units with limitations on fuel availability, as well as Guaranteed Controllable Demand Resources, Energy Storage Equipment, and thermal power plant units with periodic emission limitations. These restrictions will be defined by CENACE for each day of the Short-Term Operational Planning horizon."

Subsection 4.3.2: "The CENACE shall report daily the Assignment of the Extended Horizon Power Plant Units over a seven-day horizon for the three interconnected systems. The results of the said assignment will be published by CENACE in the certified section of the Market Information System before the closing of the receipt of the Day-Ahead Market offers. The publication must contain the following:

> Subsection 4.3.2 (g) Amounts of daily energy, in MWh that the Energy Storage Equipment will contribute to the system;
>
> Subsection 4.3.2 (h) Shadow Price, in $/MWh, associated with the energy contributed to the system by the Energy Storage Equipment."

Chapter 5, entitled Opportunity Cost, provides examples 5.6 and 5.7 of how the opportunity cost for electricity storage is calculated. Those examples[9] can be found in Appendix A, and involve Lagrangian optimization of social surplus under storage constraints. Storage constraints refer to storage capacity, operating costs, the amount of energy a storage system can provide (which in case of a battery is determined by how charged a battery is), the length of time the system can provide energy, etc. The opportunity cost calculations consider the maximum difference between the expected electricity prices and the costs of providing electricity.

Subsection 7.1.1: This Manual shall enter into force from 180 days after its publication in the Official Gazette of the Federation and must observe the following transitory provisions:

Subsection 7.1.1 (b) As long as the Shadow Prices are not published, CENACE must carry out the optimal planning of Limited Energy Resources using the models that guarantee the economic efficiency of the system;

Subsection 7.1.1 (d) Until the Guaranteed Controllable Demand Resources and Energy Storage Equipment do not reach significant levels, they will not be considered in the Medium-Term Operational Planning. CENACE will determine "significant levels", and will issue the corresponding Operational Guide once those levels are reached.

Short-Term Energy Market Manual (SENER, 2016a)

Subsection 2.9.1 (a) "In order to be able to operate and present Buy Offers in the Day-Ahead Market, the Entities Responsible for Load[10] must be accredited according to the Registration and Accreditation Manual of Market Participants and must use the formats established by CENACE.

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[8] Modelo de Coordinación Hidrotérmica y Asignación de Unidades con Aspectos de Seguridad (AU-CHT).

[9] Manual de Costo de Oportunidad, Chapter 5 "Costos de Oportunidad", pg 39 – pg 44 , Retrieved from: https://www.cenace.gob.mx/Docs/MarcoRegulatorio/Manuales/Manual%20de%20Costos%20de%20Oportunidad%20DOF%202017%2010%2016.pdf

[10] The Electricity Market Basis 2.1.47 defines an Entity Responsible for Load as "Any representative of Load Centers: Basic Service Providers, Qualified Service Providers, Last Resort Providers, Qualified Market Participating Users or Intermediation Generators" (SENER, 2015)

Likewise, the Generators may make Purchase Offers, when they are duly registered, in order to supply the proper uses of said Power Plants or operate storage equipment. References to Load Centers and Load Responsible Entities, for Purchase Offer purposes, include these Power Plants and their representatives."

Capacity[11] Market Manual (SENER, 2016b)

Subsection 5.3.5 (d): "If a firm Power Plant Unit has a limited number of hours during which it can operate continuously at maximum capacity (for example, storage systems with storage limitations and discharge depth, hydroelectric plants with storage limitations in reservoirs, diesel plants with fuel storage limitations), the firm Power Plant Unit shall be deemed to have continuous operating limitations and shall be subject to the following:

Subsection 5.3.5 (d) (iv) According to this manual, in order to recognize a firm Power Plants Capacity, those power plants that require electricity from the grid to store energy must have conditions to operate at their maximum capacity for a minimum of six consecutive hours; the rest of the Firm Power Plant Units must be able to operate at their maximum capacity for a minimum of three consecutive hours. Power Plant Units that do not comply with these conditions may not accredit Capacity under the figure of Firm Power Plant Units, even if they register under a firm status. In order for them to operate under the responsibility of the Generator that represents them, these Units may only accredit Power if they are registered with non-dispatchable intermittent status, in which case they will be evaluated under the criteria applicable to the intermittent Power Plant Units."

Market Participant Registration and Accreditation Manual (SENER, 2016c)

Subsection 2.1.2 (b) "During the FIRST STAGE of the Wholesale Electricity Market, the activities of the Generator in the said market will be limited to:

Subsection 2.1.2 (b) (iii) submit purchase offers in the Short-Term Energy Market to meet Generator's own needs or to operate storage equipment."

Subsection 2.2.10: "Physical Assets in the Wholesale Electricity Market

The licensees of this storage equipment may participate in the Wholesale Electricity Market and must register as a Market Participant in Generator mode. The aforementioned equipment must be registered in the Wholesale Electricity Market under the figure of Power Plants."

Subsection 2.3.6: "The licensees of this storage equipment may be represented in the Wholesale Electricity Market by a Generator who might not be the owner of the said equipment. The aforementioned equipment must be registered in the Wholesale Electricity Market under the figure of a Power Plant. The registration and operation of storage assets considered part of the National Transmission Network or of the General Distribution Networks will be subject to the regulation issued by the CRE."

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[11] In Spanish "Mercado para el Balance de Potencia" translates into English as "Capacity Market", which can lead to misunderstandings. While "potencia" in Spanish literally means "power" in English, it refers to capacity not electricity. Consequently, from this point on, "potencia" will be translated as "capacity", not as power, and "Mercado para Balance de Potencia" shall be translated as a "Capacity Market".

Subsection 4.2.6 "Procedure for initial capture and update of information of the Power Plant in the Registry Module of the Wholesale Electricity Market: The Market Participant must initiate a session in the SIM[12] and enter the Registration Module and the Asset Registration section, to capture the general information, as well as reference and technical parameters of the Power Plant and Units of Power Plant, in accordance with the following. In the case of Joint Ownership Units, all the information contained in this numeral will be recorded by the principal representative of the unit, except where it is explicitly stated that any parameter is registered by non-principal representatives."

Subsection 4.2.6 (C) "Technology type of the Power Plant (to be chosen from a list that follows)."

Subsection 4.2.6 (C) (XIV) "Electricity Storage Equipment"

Subsection 4.2.6 (J) "The storage capacity of the storage equipment. The Market Participant (Generator) representing storage equipment shall record the capacity in MW of consumption and the maximum demand in kW of the said equipment."

Subsection 4.4.3: "The Market Participants may submit this request in the form of a Basic Service Provider, Qualified Service Provider, Last Resort Provider and Qualified User Participating in the Market. A Market Participant with a Generator mode may register Load Centers if it is an Intermediation Generator or to register its facilities for its own uses or storage equipment as Load Centers."

2.2.3 Energy Transition Law Strategy

The Energy Transition Law (Congreso de la Unión, 2015) was published in 2015. The Articles 4, 5, 7, 8, 14, 18, 21, 24, 25, 26 and Chapter III are some of instances where the law makes a reference to a strategy to promote the use of cleaner fuels and technologies. The fifteenth transitory article of that law states that the said strategy should be published within a year of the publication of the Energy Transition Law.

In 2016, SENER published an Accord detailing the first strategy (SENER, 2016g) which the new administration (whose term commenced in January of 2019) has not updated at the time of writing of this document, making it still a prevailing approach towards cleaner fuels and technologies.

The Accord recognizes the importance of batteries not only at the level of distributed generation (Subsection 3.1.3.3), but for the country as a whole in terms of energy security and achievement of climate change goals through facilitation of renewable generation technologies (Subsection 3.1.3.3.3). The services batteries offer and their potentially integral role in grid stability and reliability is also recognized.

The Chapter 7 of the Accord lists the policies and actions towards the energy transition. There are three lines of actions:

- Efficient use of energy
- Exploitation of clean energies
- Development of integrated infrastructure

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[12] Sistema de Información del Mercado

The development of energy storage was grouped under the "development of integrated infrastructure". The specific actions associated with energy storage are outlined in the tables below.

Table 2.2. Specifications associated with energy storage in the Energy Transition Law. Source: Table 17. Actions in Energy Storage (SENER, 2016g)

Category	Lines of Action
Public Policy and Regulations	Develop specific regulations in the Grid Code (*Código de Red*) for the interconnection of energy storage systems. Recognize in Electricity Market Basis special characteristics of energy storage related to their contribution of ancillary services, considering the needs and opportunities of the network for their integration. Develop specific regulations for the construction, performance and removal of energy storage systems.
Institutions	Develop a Road Map that identifies convergent objectives, needs, challenges and priorities for the deployment of energy storage systems. Publish Electricity Market information that facilitates the modeling of energy storage systems.
Human Resources and technical capacity	Integrate the energy storage topic into the Strategic Program for Training Human Resources in Subject of Energy.
Markets and Financing	Promote the development of business models which will boost technology, and create products and services for the energy storage value chain
Research, Development, and Innovation	Promote energy sector investment into energy storage research and development, studies, research projects, and innovation. Promote national and international collaboration in research, development and innovation in storage technologies, considering the present collaboration agreements as Mission Innovation.

Table 2.3. Energy Transition Law Strategy performance indicators in the area of energy storage. Source: Table 18 Table of Indicators of the Strategy and Its Baselines (SENER, 2016g)

Energy Storage	
Indicator	Baseline
Increase in storage capacity due to renewable energy	Installed storage capacity as a function of installed intermittent energy capacity (solar and wind). Base year (2016): 0% Source: SENER
Increase in total storage capacity	Total installed storage capacity. Base year (2016): <5 MW Source: SENER

The Accord ends with (not legally binding) conclusions and recommendations. One of the conclusions is to transform the electricity sector from a system with large centralized plants to one that integrates small generators located at the points of consumption, fed by clean energy and backed by storage systems. This conclusion is aligned with Mexico's international decarbonization commitments.

The recommendations are directed to Federal Public Administration and decentralized autonomous agencies, the electric industry at large, and the state-owned power companies.

The recommendations related to energy storage for Federal Public Administration and decentralized autonomous agencies are to develop specific regulation for technologies and services related to energy storage. The recommendations for the state-owned power companies and the electric industry at large are to conduct studies and pilot storage projects to understand the cost-benefit of the various technologies for the power grid, distributed generation and isolated supply.

On February 7, 2020, the update of the Transition Strategy to Promote the Use of Cleaner Technologies and Fuels is published, in terms of the Energy Transition Law, in whose Table 32 the actions regarding energy storage are confirmed (SENER, 2020).

2.2.4 Ancillary Services

The laws and regulations which apply to ancillary services, apply to electricity storage when it offers those services.

The Article 3, XLIII of the LIE defines ancillary services as "the services related to the operation of the National Electric System and that are necessary to guarantee its Quality, Reliability, Continuity and safety, which may include: operational reserves, rolling reserves, frequency regulation, voltage regulation and emergency start-up, among others, defined in the Market Rules." (Congreso de la Unión, 2014).

The LIE also mentions in Article 96 II that the Electricity Market Rules shall determine the procedures that will allow buying and selling of ancillary services included in the wholesale electricity market and in Article 138 V, and that the CRE shall determine the tariffs for ancillary services not included in the wholesale electricity market.

The Electricity Market Basis state that the system operator CENACE must procure ancillary services (SENER, 2015[13]), namely:

- Primary Regulation (frequency control)
- Reserves
    - Secondary Regulation
    - Spinning Reserves
    - Non-spinning Reserves
    - Operating Reserves
    - Supplementary Reserves
- Voltage control and reactive power
- Black Start and interconnecting to the grid, operating in island mode

[13] Basis 6.2.1

The Primary Regulation is a mandatory service that must be provided by all the Power Plant Units and will not be remunerated by CENACE (SENER, 2015)[14].

The ancillary services not included in the MEM (voltage control and reactive power, black start and interconnecting to the grid, operating in an island mode) are remunerated through tariffs established by the CRE (SENER, 2015)[15].

Electricity market participants are required to acquire reserves (ancillary services included in the market), and those requirements are determined by zone (SENER, 2015)[16].

3. Identification of Barriers and Enablers for Electricity Storage in Mexico

The growing participation of intermittent renewable energy sources, in part driven by the international decarbonization commitments, has triggered interest in electricity storage systems (ESS) from both public and private sectors. Nevertheless, the ESS are facing various challenges. Those challenges have been discussed in various working groups held by industry stakeholders. Consequently, previous work on the subject is summarized below.

3.1 Previous Work

This section reviews work done by the Department of Energy (SENER), National Electricity and Clean Energies Institute (INEEL), the Energy Regulatory Commission (CRE), and the private sector to identify the barriers for electricity storage in Mexico. The focus is on barriers, because there are no enablers, beyond the aforementioned legal references, which permit storage to operate under limited conditions.

3.1.1 SENER Working Group

In May of 2016, SENER kicked off an Energy Storage Working Group (SENER, 2016 d,e,f) tasked with producing recommendations and actions as inputs for the "Transition Strategy to Promote

[14] Basis 6.2.5

[15] Basis 6.2.6

[16] Basis 10.4.3

the Use of Cleaner Technologies and Fuels" (SENER & CONUEE, 2016). Those recommendations and actions were to be articulated through the Energy Advisory Council. The Article 87 of the Energy Transition Law states that the Council shall be a permanent citizen participation and consultation body whose purpose is to transmit public opinion and advise SENER on the actions necessary to comply with the goals in matter of clean energy and energy efficiency. The working group met over three workshops, and was composed of the public and private sector participants.

The Energy Storage Working Group focused on identification of barriers and corresponding remedies for energy storage. The group had five goals:

i. Analyze the current state of available technologies, and international best practices related to energy storage.
ii. Evaluate the possible role that storage technologies may play in the national energy system.
iii. Identify the key actors involved in the development of the public policy and deployment of energy storage technologies in Mexico.
iv. Define actions that have to be done (according to high, medium and low priority level), and by whom (over a short-, medium- or long-time horizons).
v. Suggest public policy instruments that facilitate deployment, research and development, and assimilation of available energy storage technologies.

The group had two overarching goals: to present a set of actions and recommendations as an input for "The Transition Strategy to Promote Cleaner Technologies and Fuels", and to create a report on the prospects of implementation of energy storage in Mexico. To that end, the working group was to identify the conditions necessary to adopt energy storage technologies. The group was divided into five sub-groups focused on actions necessary to promote storage, considering: 1) legal, 2) political, 3) economic, 4) technological, 5) social and environmental issues. The product of each sub-group focused on actions and recommendations which would promote electricity storage.

3.1.2 National Electricity and Clean Energies Institute (INEEL) Workshop

In November 2018, INEEL held a workshop on national research priorities, technological development, and training in the field of energy storage. The workshop participants were divided into eight workgroups:

1. The value and benefits of energy storage.
2. Thermal storage technologies.
3. Electrochemical and chemical storage technologies.
4. Electric storage technologies.
5. Mechanical storage technologies.
6. Standards, certification, regulatory framework and public policies.
7. Experiences of the application of storage systems.

8. Usefulness of demonstration projects.

Although the INEEL workshop principally focused on the technical aspects of energy storage and examined in detail attributes of different storage technologies, it also identified a number of barriers to deployment of storage systems.

3.1.3 CRE Working Group

In 2018 CRE organized a workgroup composed of private and public sector stakeholders, to explore ways of integrating energy storage into the national electric system (SEN). The group considered the regulatory framework from a private sector perspective, and identified various barriers for deployment of energy storage. The group focused on short-term regulatory solutions that could be implemented almost immediately.

3.1.4 The "Electrical Energy Storage in Mexico" Report

The German Society for International Cooperation (GIZ) in conjunction with Gauss Energy, has conducted a study "on the technical and commercial prefeasibility of integrating a Battery Energy Storage System (BESS) into an existing PV plant. The PV plant is a 15 MWDC / 10.5 MWAC extension of the existing 30 MWAC Aura Solar 1 PV plant near La Paz in Baja California Sur, Mexico" (GIZ, 2019).

The report considers the current Mexican regulatory framework in its development of commercial scenarios for battery storage intended for generating additional revenue for the PV plant. Although the report does not name regulatory barriers per se in terms of the regulatory framework, it does mention that "the delivery of the of ancillary services through a BESS is currently not economically feasible due to unclarity in the market situation"[17].

In general terms, the last section of the report, drawing on international experiences, describes how governments can foster or hinder implementation of energy storage.

3.2 Reviewing Barriers and Next Steps

Although the working groups were organized independently, and included diverse participants, they produced a number of comparable conclusions, based on similar assumptions. Specifically, all working groups adopted three implicit hypotheses:

1. The benefits of electricity storage exceed storage costs. This assumption is a prerequisite for any meaningful energy storage discussion, where terms "costs" and "benefits" can encompass numerous relevant dimensions: financial, socioeconomic, environmental, strategic, etc. Some of the benefits mentioned during workshops suggested that storage would:

[17] Gauss report pg. 51

- Promote renewables by reducing intermittency and strengthening their technical and economic "raison d'etre".
- Reduce the price of electricity through peak shaving, reduce agricultural and domestic electric tariff subsidies and promote development of storage industry.
- Reduce greenhouse gas emissions.
- Provide flexibility and reliability to the grid while making it technically stronger.
- Promote distributed generation and access to energy by isolated communities

2. The investment in storage should be borne by electricity generators. An overwhelming number of suggestions made by the working groups was aimed at regulatory changes which would create favorable market conditions for investment by market participants. In this case, "market participants" broadly refers to all market participants which have to compete with one another, including publicly-owned CFE.

3. Storage systems should be integrated into the grid through electricity market. This point is corollary to the previous one.

Accordingly, the review of barriers to deployment of storage was considered from a perspective of obstacles to its deployment.

All working groups have identified inadequate regulatory framework as the principal barrier to storage. Since there is no regulation specifically focused on storage, and the existing general regulation would be incomplete:

- There is no clarity of how CENACE would represent storage in a short-term market optimization model since the guidelines still have not been published.
- It is not clear how storage could offer ancillary services not included in the market, nor the remuneration methodology used to pay for those services.
- The uncertainty whether acquisition of ancillary services applies to storage.
- Under current regulation there is no market (or tariff) for rapid frequency response, a service that storage could offer to the grid.
- No efficient connection guidelines of storage to the grid.
- There is no clear regulation on environmental, safety, or efficiency standards for storage, unclear building codes, etc.
- Regulatory treatment of storage in terms of carbon tax and clean energy certificates (CEL) is not clear.
- The regulatory framework does not provide a long-term revenue certainty associated with storage investment.

Other barriers to storage identified by workshop participants include:

- High cost of storage.
- Limited knowledge of the impact of variable renewable generation on the network.
- Lack of investment incentives for its deployment.

The social aspect of energy storage has not been discussed in regulatory context. It is curious, because arguably the main driver of energy storage is proliferation of intermittent renewable energy, driven by the social concern for climate change. In short, energy storage creates benefits to society which are neither remunerated nor adequately addressed in the existing regulation.

After summarizing the barriers and enables to storage identified at the industry stakeholder meetings, we will make a case for acknowledging social benefits in the regulatory framework.

3.3 Additional Barriers and Next Steps

There are a few additional barriers to deployment of storage that were not mentioned by the working groups, or not elaborated enough. For example, the manner in which storage can participate in the capacity market could be seen as a comparative disadvantage.

Before discussing energy storage in context of the capacity market, it might be beneficial to review the Capacity Market Manual[18] in more detail. The fifth section of the Capacity Market Manual (SENER, 2016b) describes capacity compensation. The subsection 5.1.1 of the Manual states:

"The amount of Capacity that CENACE will accredit to each Resource for the purposes of the Capacity Market (expressed in MW-year) will correspond to the Delivered Capacity by that Resource to the National Electric System (expressed in MW) during the Year of production."

Subsections 5.2 and 5.3 explain how deliver capacity and availability of physical production are calculated, respectively. Subsection 5.3.2 states:

"The Availability of Hourly Physical Production will be calculated by CENACE for each Critical Hour and differently for the Jointly Owned Units, the Intermittent Power Plant Units, the Firm Power Plant Units and the Guaranteed Controllable Demand Resources in accordance with (...) sections 5.3.3, 5.3.4, 5.3.5 and 5.3.6, and observing the following provisions:

(a) Before calculating the Availability of Hourly Physical Production, each Power Plant Unit shall be classified as intermittent or firm based on the rules established herein:"

"(ii) Limited energy resources: Any Power Plant Unit considered as a limited energy resource in accordance with Base 6.5.1 will be classified as intermittent for purposes of Capacity accreditation if the restriction of limited generation of said resource is required. is managed by CENACE on a daily, weekly, or monthly cycle in accordance with Base 6.5.8, or by another entity, if applicable, in order to achieve the optimization of limited energy resources. Examples of such limitations are the minimum reserve limitation and the maximum reserve limitation for hydroelectric power plants (stored energy). If a Power Plant Unit is considered a limited energy resource in accordance with Base 6.5.1 but is managed on a seasonal, annual or multi-year cycle, it will be classified as firm.

(iii) Other resources: Any Power Plant Unit that is not included in any of the two previous rules will be classified as firm."

[18] In Spanish "Mercado para el Balance de Potencia" literally translates into English as "Power Balance Market", which can lead to misunderstandings since it refers to capacity market and not power trading, as explained in footnote #11. Capacity is measured in MW, and refers to volume of electricity that can be generated. It can be thought of as a pipeline diameter. Electricity market refers to active power, measured in MWh, and it can be thought of as water flowing through the pipeline. The bigger the pipeline diameter, the greater amount of water that can flow through it.

In terms of capacity compensation, the intermittent resources are remunerated for the capacity offered during the 100 critical hours. The Subsection 5.3.4, "Availability of Hourly Physical Production for Intermittent Power Plant Units", states that:

"(a) The Availability of Hourly Physical Production of the Power Plant Units classified as intermittent will be expressed in MW and will correspond to the **physical amount of energy applicable at each Critical Hour** for purposes of generation liquidations under the rules of the Short Energy Market Term, corresponding to the energy delivered at the Interconnection Point. This amount will be reduced for own energy uses before delivery to the Interconnection Point, but it will not be reduced for amounts contractually committed (for example, it will not be net of contracted energy) and will not be adjusted for transmission or distribution losses that could occur beyond the Interconnection Point."

On the other hand, the firm units are remunerated according their availability. The Capacity Manual, Subsection 5.3.5 "Availability of Hourly Physical Production for firm Power Plant Units" states:

"(a) The Availability of Hourly Physical Production of the Power Plant Units classified as firm will correspond to their **maximum availability** to produce net energy for their own use and will be calculated for each Critical Hour according to the following formula: (...)

(d) If the firm Power Plant Unit has a limitation on the number of consecutive hours that it can operate at its maximum capacity (for example, storage systems with storage limitations and depth of discharge, hydroelectric plants with storage limitations in reservoirs, diesel power plants with fuel storage limitations), the firm Power Plant Unit shall be considered to have continuous operating limitations and shall be subject to the following:

(iii) Firm Power Plant Units with limitations of continuous operation may not credit the Availability of Hourly Physical Production in a number of consecutive Critical Hours that exceed their limitations of continuous operation. The Availability of Hourly Physical Production will be considered to be zero for consecutive Critical Hours that exceed these limitations. Said reduction will be made even when the firm Power Plant Unit is not dispatched.

(iv) For purposes of Capacity accreditation under the terms of this Manual, the firm Power Plant Units that require the supply of the electrical network to store energy, must have conditions to operate at their maximum capacity for a minimum of six consecutive hours; the rest of the firm Power Plant Units must have conditions to operate at their maximum capacity for a minimum of three consecutive hours. The Power Plant Units that do not comply with these conditions will not be able to accredit Capacity under the figure of firm Power Plant Units, even when they are registered with firm status. In order to operate under the responsibility of their representatives, these Units may only accredit Capacity if they register with non-dispatchable intermittent status, in which case they will be evaluated under the criteria applicable to the intermittent Power Plant Units."

The key point is that storage resources face more stringent set of rules to be classified as firm power plants (operation of six consecutive hours vs. three consecutive hours), and not as intermittent resources. Storage classified as firm is remunerated for its availability, not for its utilization. Conversely, an intermittent resource does not get paid for availability per se but for capacity utilized during 100 critical hours to deliver energy. Put differently, if the capacity offered by a firm plant coincides with the critical hours, it will receive capacity payment corresponding to the number of critical hours it was available, regardless of whether it produced electricity during that time.

The intermittent capacity, on the other hand, only gets remunerated in proportion to the critical hours during which it provided the service. This could be considered an unnecessary barrier to entry, since according to CENACE's forecast of 2019 critical hours, 66% were composed of three consecutive hours, or less, and 78% were 4 consecutive hours or less (CENACE, 2020).

It is also important stress that the term "Capacity Market" is unlike energy market where parties buy and sell electricity with immediate price signals in response to changes in demand or supply. The capacity price determined by the 100 critical hours in the Mexican Capacity Market is unknown until February of the following year, when CENACE calculates and publishes the capacity tariff per MW in each electrical system (Baja California, Baja California Sur, and SIN). There are virtually no Capacity price signals between one February and another. In other words, market participants offer capacity to the market without knowing how much they will be paid, or if at all in case of storage, if that capacity is not offered during 100 critical hours.

An assumption that 100 critical hours coincide with high market prices and therefore represent time periods during which storage provides are likely to offer energy to the market (i.e. are likely to be paid for capacity) is also misleading, That is because the 100 critical hours are not determined by energy prices but by the minimum excess capacity gap, or the minimum differences between demand and supply during the year. Those differences can coincide with high demand and high prices, but not necessarily. The table below indicates the time of day during which CENACE expected the critical hours to occur. Almost 40% of the time, critical hours fall between 11pm and 5pm, hours which traditionally are not associated with peak demand[19].

Table 3.1. CENACE's 2018 forecast of 2019 critical hours.

Critical Hour starting at:	00am	2pm	3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm	11pm
Frequency	8	1	1	2	3	1	20	4	9	27	24

Source: CENACE, 2020

In summary, there are two interrelated capacity market barriers to storage participation. The first barrier relates to more stringent conditions faced by storage - compared to conventional generation - to be classified as firm capacity. Having more difficulty being classified as firm capacity creates difficulty being paid for availability. Thus, the second barrier corollary to the first barrier, refers to the fact that while firm capacity is remunerated for availability, the intermittent capacity is not. This could be considered as a disincentive to storage investment.

[19] From last Sunday in October till Saturday preceding first Sunday in April, CFE defines peak hours between 6pm and 10pm, and from 8pm to 10pm for the remainder of the year. In California, peak hours are between 4pm and 9pm. https://app.cfe.mx/Aplicaciones/CCFE/Tarifas/Tarifas/tarifas_negocio.asp?Tarifa=HM. & https://www.energyupgradeca.org/time-of-use-faqs/#:~:text=The%20peak%20demand%20period%20is,of%20business%20during%20this%20time.

Also, it is worthwhile noting that long-term auctions which procure power plant capacity are geared towards conventional generation, and consequently do not specify time limits for provision of power. This is another barrier for full storage participation in the energy markets, especially since contracts from long term auctions provide relative long-term security from market volatility.

Finally, from a "big picture" perspective, the obstacles to deployment of electricity storage in Mexico can be grouped into commercial, market and regulatory barriers.

Commercial Barriers

The most common commercial barrier deals with the high cost of electricity storage systems themselves. An electricity storage system has to earn enough to:

- Pay for electricity it has stored (which implies paying not just for the cost of electricity per se, but the cost of capacity used to produce that electricity).
- Pay the cost of transmission of electricity used for charging storage facility
- Pay for the storage infrastructure.
- Pay for energy loses.
- Earn enough return to make the investment in storage attractive.

Consequently, in order to overcome the commercial hurdles, it is essential to have a favorable market structure and regulatory framework.

Financial Barriers

Currently there is no financial framework for grid-scale electricity storage in Mexico. There are no fiscal incentives for grid-scale storage, nor are there financing mechanisms specifically geared towards storage. In contrast, there are fiscal incentives for renewable generation. Specifically, Article 34 of the Income Tax Law indicates maximum deductions related to fixed assets. The incision XIII of the said article states that "100% for machinery and equipment for the generation of renewable energy or energy from efficient cogeneration" is deductible.

Various other countries have different types of incentives to promote renewable energy. While Australia has tax incentives, in the UK the government installed a Renewable Heat Incentive where which provides a financial support to the owner of the renewable heating system, for seven years.

Market Barriers

Arguably, the current Mexican market structure is not favorable towards energy storage. The remuneration methodology for regulated ancillary services is not defined, and the market for ancillary services included in the whole sale electricity market is short-term.

A short-term market structure does not favor capital-intensive investments, which explains why there is no merchant power plants in Mexico. The volatility of revenues associated with short-term market poses too much of a risk for a potential investor, and that is why all independent power producers in Mexico have a long-term contract with either the CFE or a private sector client that partially or fully anchors their investment. Arguably, energy storage systems represent equally capital-intensive investments, which are not likely to materialize unless revenue security associated with long-term contracts is made available to them.

Arguably, there is also problem where those who benefit from positive externalities associated with electricity storage do not pay for those externalities, such as reduced energy prices due to reduced congestion, reduced transmission infrastructure investment, and reduced use of peaker plants. Under ideal regulatory and market conditions not monetizing positive externalities associated with storage would, ceteris paribus, result in undersupply of storage.

Regulatory Barriers

The most quoted barrier to deployment of energy storage in Mexico is the deficient regulatory framework which doesn´t permit utilization of all the services that energy storage is technically capable of offering. The regulatory framework deficiencies vary from preventing ancillary services from being offered, to creating market barriers by creating disputably excessive storage capacity requirements (min. 20 MW in order to be able to offer capacity availability as opposed to only be remunerated if the plant is actually operating during the 100 critical hours), to establishing interconnection norms or clear environmental guidelines specifically for storage systems.

The current regulatory framework, specifically the Electricity Market Basis 3.3.21 (SENER, 2015) virtually eliminates the possibility of standalone electricity storage by requiring storage to assume all responsibilities of a load center, and all responsibilities of a generator, resulting in double payments. Currently in Mexico generation pays 30% of the cost of transmission, and load pays 70%. For example, a plant supplying one MWh directly to a client, will pay 30% of transmission cost when 1MWh is injected into the grid, and the client will pay 70% (30%+70%=100%). If the same MWh travels through storage, the plant will pay 30% of transmission cost when 1MWh is injected into the grid, and storage will pay 70% when it receives it. If five minutes later storage injects that MW into the grid to send it to the client, it will now pay 30% of transmission cost, and the client will pay 70%, resulting in a 200% payment for transmission costs (30% generator injecting + 70% storage receiving + 30% storage injecting + 70% final user receiving = 200%). Put simply, the same MWh will result in 200% of transmission costs if it passes through storage, compared to being sent directly to client – even if sending that MWh through storage might decrease congestion, increase grid liability, or postpone transmission infrastructure investments. If a client is at the distribution level, aside from paying double for transmission, there will also be a double payment for distribution. There would also be a double payment for CELs, once paid by standalone storage, and once paid for by the client, again for the same MWh of electricity.

Classifying electricity storage as generation creates a number of additional barriers to storage deployment, because such a classification doesn´t recognize time constraints most storage technologies are subject to. Consequently, if time periods for provision of service are not defined, conventional generation is more likely to win capacity auctions (or any other competitive mechanism to provide capacity) than storage technologies, whose faster and more precise response time is not recognized. Also, classifying storage as generation prevents transmission or distribution from investing in storage technology, because independently of how beneficial it might be for the system, it will not be recognized as a transmission or distribution asset because of strict legal separation between generation and other market participants.

It is also important to point out that the capacity market is not regionalized. In other words, the mainland electric system is treated as one area for purposes of capacity market. It is assumed that the difference in congestion prices between nodes will indicate capacity shortages, which is not necessarily accurate. The said price difference might be related to a limited transmission capacity, as opposed to generation capacity. Alternatively, there might be no congestion, but very limited capacity, as is the case in Baja California, where significant portion of electricity consumed comes from the United States. Lack of regional capacity market makes it difficult to identify which areas are lacking generation capacity, and consequently where there is a potential need for storage systems. As a result, lack of regional capacity markets can be considered as a potential obstacle to the deployment of electricity storage systems.

Perhaps the most important barrier to implementing storage deals with the Market Basis 6.2.5 which states that primary regulation (or rapid frequency response) shall not be remunerated in the MEM. The rapid response service is one of the principal vehicles for battery storage participation in electricity markets. It provides the anchor for storage to provide other services in the market, and provides contractual stability that a day ahead market does not. Also, the existence of rapid response market in Mexico would foster the development of renewable generation which faces challenges associated with frequency control.

The barriers considered so far have been on the regulatory level. It is also important to recognize, that some barriers are derived from the legislative level, specifically the Electricity Industry Law (LIE). The LIE, which defines market participants, does not recognize electricity storage as a separate category.

Ownership vs. Control of the Storage System

Currently, an energy storage system with a capacity of 20MW or more is classified as a Limited Energy Resource, is controlled by CENACE, and is remunerated according to the Opportunity Cost Manual. This constitutes a regulatory barrier which discourages investment into storage systems over 20MW. That is because the owner of such a storage system relinquishes the control of storage without an adequate return on investment. Unlike power plants, energy storage systems have no long-term storage contracts which help to mitigate market risk and provide an adequate return on investment. A risk-loving investor might consider investing into a storage system without a long-term contract if he/she expects adequate return operating in the short-term market. Such an investor, however, would not invest if he/she is unable to control their investment. This would not be a problem if investors' and CENACE's incentives were aligned – but they are not. While investors want to maximize profit on their investment, CENACE wants to minimize it by optimizing system operations. Accordingly, in the name of optimizing system operations CENACE might charge the system when the energy is not least expensive, and might release it not when it is most expensive. The key barrier to investment is that the control of the asset is not under investors' control.

Vesting Contracts (Contratos Legados), and Hydropower Plants

In order to discuss pumped-hydro storage systems, it is important to provide a regulatory background. The Mexican energy reform broke up the CFE monopoly into various companies. One of those companies was a Default Supplier, meant to provide electricity to all consumers who chose not to participate in the MEM or were too small to do so, such as small businesses, households, or small industrial clients. The CFE Default Supplier could contract CFE generation companies using vesting contracts (Contratos Legados in Spanish). The vesting contracts were created by SENER to limit the market power of the CFE generation companies and to protect consumers from price volatility. The contract tenure was based on the age and efficiency of each power plant. Out of 150 CFE plants, 97 were hydro power plants and contracts were signed for them with a tenure between 1 and 30 years (SENER, 2017a). The vesting contracts created a fixed price for services offered by each plant, based on plant's costs[20], thereby removing incentives for the plant to withhold power supply to increase wholesale electricity prices. All of CFE's hydropower plants have signed a vested contract. With the exception of run-of-the-river mini-hydro generation, all hydropower plants in Mexico belong to CFE.

The CFE has limited incentives to implement pumped hydro storage under existing vesting contracts:

- Vested contracts have a fixed rate of return, and CFE would not be able to take advantage of market fluctuations.
- In order for CFE to build a pumped-hydro storage system, it would also have to build a new hydrogeneration plant, since all existing hydro plants are under vested contracts.
- If additional investment is made linked to the plant under a vested contract, that investment falls under the vested contract as well. Without renegotiating the contract, CFE has no incentive to make an investment that it would not be able to control.

In short, CFE competes in the electricity market with private sector participants, and it acts like a for-profit private sector participant itself. Consequently, in order for CFE to make an investment, it needs a return on that investment which it considers acceptable. However, limitations placed on CFE through vesting contracts can make earning the desired level of return on investment difficult.

Also, it is almost certain that if CFE invested into pumped hydro storage system, it would be controlled by CENACE. That is because hydro resources are generally large enough to be classified as a limited energy resource dispatchable by CENACE. In case they are not large enough in terms defined in the Subsection 2.4.3 of the Opportunity Cost Manual (described above), the Subsection 2.2.2 of the said manual states that: "CENACE will evaluate in which particular cases the hydroelectric power station units with low capacity reservoir storage and without generation restrictions, may be classified as a Limited Energy Resource, depending on whether the available energy of the unit can be assigned during Operational Planning." In other words, CENACE is likely to control a pumped hydro system independently of its size.

Finally, there are exogenous barriers to hydro storage systems related to water management issues. Arguably, hydro generation can delay and decrease water supply to users downstream from the dam. Pumped hydro could decrease that supply further buy redirecting water back into the reservoir. Consequently, it is possible that the National Water Commission (CONAGUA)[21], which is responsible for water management in Mexico (CONAGUA, 2020), might rule against some of the pumped hydro projects in the interest of downstream users, such as farming communities.

Next Steps

A more complete picture of energy storage in Mexico requires not only a look at the existing regulatory framework, but also an indication of government's vision of the role energy storage

[20] Plants costs include fixed operating and maintenance costs, labor costs, depreciation, associated infrastructure, variable operating and maintenance costs, other tariffs or costs (transmission, CENACE, CRE, water rights, etc.) (SENER, 2017b)

[21] Comisión Nacional del Agua (CONAGUA).

can play in the national electricity system. The government whose term ended at the end of 2018 outlined its approach to energy storage in documents such as an Accord issued by the Ministry of Energy, which published an update on the Transition Strategy (referred to in the Energy Transition Law (Congreso de la Unión, 2015), Articles 4, 5, 7, 8, 14, 18, 21, 24, 25, 26 and Chapter III that deals with strategy) to promote the use of Cleaner Technologies and Fuels.

The current government, whose term began in January 2019, published a 2019-2033 version of PRODESEN with a limited direct reference to energy storage. The chapter IV of PRODESEN that articulates government's new energy policy in the area of electricity mentions energy storage under the heading "IV.3 Energy Transition Policy" (SENER, 2019), in context of marginalized communities. Specifically, it states that the development of micro-networks is necessary to promote technical solutions to supply electric energy for the most marginalized and remote regions of the National Transmission Network and the General Distribution Network. Those solutions should promote energy efficiency and sustainability, and use conventional and renewable energies, energy storage systems, and information and communication technologies.

The current government's more comprehensive strategy towards storage was published in February of 2020, in an update to "The Transition Strategy to Promote the Use of Cleaner Technologies and Fuels" (SENER, 2020). The strategy identifies a number of lines of action related to energy storage in its Table 32, including:

- Development of storage specific regulation in terms of interconnection, ancillary services, construction, performance, and retirement.
- Develop a Road Map for deployment of energy storage systems and making relevant information available to facilitate storage modelling.
- Promote energy storage training, research and development, and international cooperation.
- Facilitate the development of energy storage business model.

4. Set of Measures to Overcome Barriers

The previous section describes the barriers to electricity storage identified by SENER, INEEL, CRE, and a business case study for storage in Baja California Sur. The same sources also suggest measures to overcome those barriers, and this section summarizes those suggestions. It also summarizes the recent work done by the CRE on a remuneration methodology for ancillary services, which considers electricity storage.

Whereas the barriers identified in workshops converged on regulatory shortcomings, the proposals to overcome barriers varied from one working group to another. The approach adopted by each working group to surmount barriers was determined by the working group's focus. The suggestions produced by each working group are summarized below.

4.1 SENER Working Group

The key theme of SENER working group's suggested actions and recommendations (SENER, 2016 d,e,f) to overcome barriers to storage deployment is commercialization of storage services through an electricity market. The group recommended the following actions:

- Align economic incentives of the grid operator and the investor,
- Eliminate market barriers.
- Decrease regulatory uncertainty.
- Monetize the benefits to the grid to promote deployment of storage.
- Define which activities that storage electricity storage can provide are regulated, and which are not, define remuneration of the regulated activities such as remuneration for ancillary services, determine which activities require permit. Review the possibility of applying dynamic tariffs to storage.
- Determine applicability of CELs to storage systems that are used for peak-shaving and thus, could potentially reduce emissions.[22]
- Issue a request for proposals to launch a pilot storage project and develop a special Energy Storage Program that will evaluate grid storage requirements, will consider the country goals related to renewable energy and decarbonization, and will set the national storage capacity goals. The Program will also promote information sharing with all the relevant stakeholders. In order for it to happen, there must be a political and regulatory instrument that gives certainty to the development of pilots, provides legal support and creates a favorable commercial environment.
- Adapt the existing regulatory framework and public policy to encourage access to storage, as well as research and development. Investigate whether it is necessary to create fiscal incentives or subsidies to promote storage and promote income certainty through long term contracts, minimum of 15 years. Analyze the most suitable schemes for public funding of research and development of storage, such as a Mexican Center for Innovation in Energy Storage (CEMIE), or provide pilot project guarantees through the Energy Transition and Sustainable Energy Use Fund (FOTEASE).
- Incorporate energy storage into curriculum of universities, colleges, institutes of technology, etc., to promote human capital formation, promote research and development, and establish storage as a component of economic development and value creation.
- The CRE, CENACE, and SENER need to recognize and define the technical characteristics of storage systems, and define the treatment of storage from an operational point of view. A technical analysis of a storage system is required in terms of interconnection, either as a load or as a generator.

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[22] Minutes of the Energy Storage Working Group, Third Session, Energy Transition Advisory Council May 24 to 31, 2016. Page 3. "Analizar la aplicabilidad de CELs a sistemas de almacenamiento por elementos de eficiencia óptima, disminución de factores de emisión de fuentes generadoras (por evitar generación en horas picos), entre otros; y su cumplimiento con la definición de energía limpia".
https://www.gob.mx/cms/uploads/attachment/file/118020/Minuta_3a_Sesi_n.pdf

- Define when storage should be treated as generation, and when it should be treated as transmission or distribution. Analyze whether electricity storage should be classified as generation[23].
- Evaluate the social and environmental effects of integrating energy storage systems into the grid on climate change mitigation and integration of renewable generation to ensure the most energy efficient technologies are promoted, in terms of the net energy balance as well as the quantity and quality of the services they can offer. The impacts of deployment of energy storage technologies need to be minimized at the end of their useful life, and it needs to be aligned with deployment of electric vehicles, distributed generation and isolated supply.
- Take advantage of the existing hydroelectric plant infrastructure to maximize pumped hydro storage before using green field sites.

The sub-group also recognized the need to evaluate how electricity storage can help energy-deprived communities, suggesting that storage benefits could include lower electricity tariffs and increased power reliability. Educating people about the benefits of electricity storage could facilitate social acceptance of storage technologies and promote social inclusion.

4.2 INEEL

The INEEL workshop focused on national priorities for research, technological development, and training of human resources on the subject of grid electricity storage, has identified the following opportunities to promote energy storage:

- Develop standards for energy storage systems[24] and their interconnection with the power grid (particularly converters).
- Establish a clear business model for energy storage.
- Establish an appropriate system for the valuation, quantification and remuneration of the benefits for the rapid response energy storage can provide to the network.
- Transform the distributed generation interconnection manual into a Distributed Resources manual.

4.3 CRE Workgroup

In light of the urgent need for flexible energy solutions driven by significant penetration of renewable generation in Mexico, the CRE workgroup focused on short-term solutions meant to integrate electricity storage into the grid. The proposals to existing regulation were grouped

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[23] Minutes of the Energy Storage Working Group, Third Session, Energy Transition Advisory Council May 24 to 31, 2016. Page 1. "Sin embargo, dado que no es generación per se, es necesario evaluar como qué tratamiento se da al almacenamiento cuando forma parte de la central de generación y cuando forma parte de la red de transmisión/distribución. No es claro su tratamiento cuando ofrece servicios y no solamente generación". https://www.gob.mx/cms/uploads/attachment/file/118020/Minuta_3a_Sesi_n.pdf

[24] "systems" includes energy storage equipment

under the headings of: Regulatory Changes, Technical and Safety Standards, Environment, and Remuneration.

CRE Working Group Proposal of: Regulatory Changes

- As an alternative to introducing an "energy storage" asset class, the CRE could define a "stored energy" transaction in the wholesale market, which would clarify the activities of "storing" and "releasing", terms used in the Opportunity Cost Manual.
- Differentiate between associated storage (associated with a power plant at the same interconnection point) and non-associated storage, which takes the energy from the grid.
- For associated storage, the system operator CENACE should not need any additional infrastructure studies related to storage if the storage capacity does not surpass the capacity of the plant, and if the combination of delivered plant-storage capacity never surpasses the installed plant capacity.
- Generation permit for associated storage, where storage capacity is less than or equal to the plant capacity, should not be viewed as an increase in overall capacity if the capacity delivered to the system does not exceed the capacity declared on plant's permit.
- If a load procures storage for its own needs, it does not intend to export energy to the grid, and the storage is not associated with a plant, then a generation permit for storage should not be required (unless the storage capacity surpasses the load), and the case should not be treated as an Isolated Supply.
- The methodology used to declare the day-ahead generation profile and forecast, in line with the generation permit and the interconnection contract, should include storage operations.
- The Dispatch Verification Manual for Dispatch and Ancillary Services Instructions should be published, as referenced in the Short-Term Energy Market Manual (3.1.1)[25].
- Define the costs a generator operating the storage system should assume, if he offers ancillary services. For example, if CENACE requires reactive power, should the generator pay transmission tariff for the stored energy that CENACE needs?
- Specify in the Opportunity Cost Manual that the energy and capacity requirements necessary to be classified as a Limited Energy Resource (dispatchable by CENACE) refer to the power and capacity offered to the grid, and do not include own energy use.
- State in the Opportunity Cost Manual that a market participant has an option, its storage capacity notwithstanding, of opting out from being a Limited Energy Resource.
- Define electricity injected into storage as electricity for own use, thus liberating storage from responsibilities associated with a load center.

CRE Working Group Proposal of: Technical and Safety Standards

[25] http://www.diputados.gob.mx/LeyesBiblio/regla/n463.pdf

- For storage operating with electrochemical batteries, it is recommended to follow international standards defined by prominent organizations such as the United Nations and the International Electrotechnical Commission.
  - Safety standards for Lithium-Ion batteries to reduce the risk of fire or explosion.
  - Safety standards for battery systems: guidelines for the design of battery pack package, mechanical structure, and electrical safety test specifications.
  - Safety Standards for installing battery energy storage.
  - Standards for the fire protection systems used in the battery energy storage facilities.
- Increase the number of authorities performing verifications.

CRE Working Group Proposal of Regulatory Modifications Related to Environment

- Define the Environmental Impact Statement (MIA, for its acronym in Spanish) of standalone (not associated) electricity storage.
- Include storage in the MIA of a plant that the storage is associated with.
- Modify MIA when storage is associated with a plant that already has an environmental impact authorization.
- Specify whether it´s necessary to conduct an environmental risk assessment of storage facilities as a complement to MIA.
- Establish environmental regulations and authorizations considering applicable international standards.

CRE Working Group Proposal of: Remuneration of Storage Systems

- Current regulation does not consider all the services that energy storage can provide. Regardless of whether electricity storage is or is not associated with an electric power plant, regulation should permit it to offer all the services it is technically capable of providing. To that end, it is essential to define within the regulatory framework services necessary for the proper functioning of the national electric system that can be supplied through storage.
- It is important to define remuneration methodologies, which cover the costs of storage technologies (fixed and variable) and a reasonable rate of return.
- Remuneration of operating costs:
  - When considering variable costs in a storage tariff, consider avoided costs associated with the service provided.
  - Ensure that net benefits to the national electric system are considered in the tariff.
- Remuneration of capital costs:

- Through a fee that equalizes costs of storage with costs of a standard power plant to allow a storage system to compete on an equal footing and / or,
- Allow storage associated with a primary source of renewable energy, to benefit from the same tax incentives, such as the accelerated depreciation benefit and zero rate of the general import tax, which the renewable power plants enjoy.

Provide a long-term contract for standalone energy storage through an auction, focused on services required.

4.4 The "Electrical Energy Storage in Mexico" Report

The principal focus of the report (GIZ, 2019) was to examine whether in Baja California Sur, energy storage investment can be justified by the energy arbitrage with electricity that would otherwise be curtailed.

Although it was not the objective of the report to analyze regulations favorable for electricity storage, it did cite international practices that promote storage, such as partial or complete funding of storage, funding of energy provided by storage, or technical requirements which favor storage (such as speed or accuracy). As a general recommendation, the report suggested publishing technical requirements in English to lower barriers for foreign investors, and that funding of storage (if it is being considered) be partial to encourage implementation of economic systems.

In terms of technical recommendations, the report suggested clarifying technical procedures and conditions for connecting storage to the grid, express technical requirements for storage over finite periods, and use storage facilities first to provide ancillary services before employing slower units.

The market recommendations consider long-term arrangements for ancillary services to decrease risks for investors. In addition, ownership of storage by the grid operator CENACE could be considered for ancillary services that are not related to the wholesale electricity market.

4.5 Ancillary Services and Electricity Storage

Throughout 2018, the CRE (the Mexican Energy Regulatory Commission) had been working on a remuneration methodology for ancillary services not included in the wholesale electricity market (the MEM, for its acronym in Spanish). However, the said methodology did not consider energy storage as a possible provider of those services. Consequently, in January of 2019 the CRE engaged in a project to develop a regulation proposal for the implementation of energy storage in the national electric system and to generate the necessary inputs for the regulation of ancillary services.

The work was organized into three stages. The first stage focused on services energy storage could offer under the existing regulatory framework. The second stage offered a regulation proposal dealing with storage, and the third stage was dedicated to possible legal modifications changes derived from the first two stages.

While the final product was not available at the time this section was written, the CRE reached out to a limited number of stakeholders to discuss some of the proposals that were being considered in light of the increasing share of renewable generation:

- Classify energy storage as a marketer, not as a generator.
- Consider lowering the 20 MW storage capacity necessary to be considered a capacity provider in the Balancing Market independently of operating during the 100 critical hours26.
- Over the long-run consider modifying LIE to recognize electricity storage as its own category, and not as a generator, marketer, transmission, or distribution.
- Introduce new products into the MEM, such as frequency control, ramp control, load following, congestion relief, and infrastructure investment avoidance.

4.6 An Alternative Proposal

The discussion of barriers and enablers for implementation of storage technologies began with the review of hierarchy of laws and regulations. This section proposes regulatory changes at the level of the Energy Regulatory Commission (CRE) without modifying the Electricity Industry Law (LIE). The CRE cannot modify or create laws and it is not responsible for a national energy policy. However, it is responsible for interpreting existing laws through regulations[27]. This section combines new and previously reviewed ideas on how to overcome barriers to electricity storage by modifying regulation within the existing legal context.

At this point it is essential to make implicit assumptions explicit. Up to now, the barriers to electricity storage referred to obstacles storage systems faced in participating in the MEM or in offering ancillary services not included in the MEM to CENACE. This is not the only manner in which storage systems can participate in the National Electric System (SEN). Before suggesting regulatory changes, it is important to have a clear vision of the goal's regulation is meant to achieve. For example, regulatory changes to promote storage market will differ from regulatory changes necessary for SENER to sign a PPA type of contract with a storage provider.

Consequently, in addition to reviewing previous work on possible modifications to the regulatory framework it is paramount to contemplate the modes in which storage could participate on a grid scale, and the report will ponder the positive and negative aspects of each participation mode from a social and investor (CFE or Independent Power Producer (IPP)) perspectives.

[26] The Market Basis, in section 11.1.5, the 100 critical hours for 2018 onwards are defined as the hours with lowest amount of available reserves defined as the difference between the available generating capacity and the demand was smallest.

[27] Change in regulations imposed by the CRE also implies changes in subordinated regulations

4.6.1 Scope of Discussion and Basic Assumptions

Arguably there are four types of grid-scale electricity storage systems that can be grouped under two headings:

- Associated (at the same interconnection/connection point):
    - with generation
    - with generation for own use (isolated supply)
    - with a load center
- Standalone (draws electricity from, and unloads electricity to the grid)

The discussion will focus on standalone storage and storage associated with generation[28]. The isolated supply is by definition dedicated to satisfying own needs and according to LIE, Article 22 (SENER, 2014), the energy associated with isolated supply does not flow through transmission and distribution networks. If a plant has part of its generation capacity dedicated to isolated supply and part interconnected to the grid, and the latter part is coupled with storage, it falls within the scope of associated storage.

It is assumed that the principal purpose of a storage system associated with a load center is to ensure reliability of power supply, and to decrease load's energy and transmission costs by decreasing peak demand and peak transmission capacity used, respectively. Although a load center might be more likely to offer demand response[29] if it is backed by an energy storage system, the underlying assumption is that a load center is principally associated with a storage system for reliability of supply. As such, electricity storage for end-use is not the focus of this discussion.

Promoting either the associated or standalone electricity storage systems implicitly assumes regulatory and market conditions which foster private sector[30] investment, which can take place under the following two scenarios:

1. An investment is a result of a market-driven business decision to participate in the wholesale electricity market (MEM), and services that the asset offers are controlled by the investor[31].
2. The investment is a result of a competitive auction held by a government agency (such as the CENACE or SENER) or a government-owned enterprise (such as CFE Transmission or Distribution) which controls the storage capacity and the services it can offer.

It is assumed that under both scenarios the private sector owns and operates the storage system.

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[28] From this point on, "associated storage" will refer to storage associated with renewable generation unless specified otherwise.

[29] Demand Response refers to the availability to not consume energy when required, and being paid for that availability.

[30] The state-owned CFE generation companies fall under the "private sector" label, since their decision making is a function of expected return vis-à-vis estimated risk.

[31] This description also includes ancillary services not included in the MEM, since the investor decides whether or not to offer those services to CENACE

4.6.2 Overcoming Barriers: Control, and Market Structures

On account of relatively high price of storage compared to conventional generation, it is important to market all the services storage can offer to recuperate the investment; the so called "value-stacking". The benefit of value-stacking is not just about increasing the sources of revenue, but also about diversifying the sources of revenue. This point is important because relying on only one service storage can provide to recuperate the entire investment makes the price of that service relatively uncompetitive. Distributing the cost of the entire investment across various services makes those services much more competitive, especially in Mexico where regulated tariffs are based on costs. The structure of value stacking is determined by the combination of storage technology and specific necessities at a site where the storage is located. Value stacking is very important because in order for the private sector to invest, it must have a reasonable confidence that it can recuperate that investment and earn an acceptable return proportional of the associated risk.

Below, we consider the enablers and the conditions necessary for private sector investment in associated and standalone storage controlled by the investor or the CENACE.

	Standalone Storage	Associated Storage
Market	A Market-Driven Standalone Storage	B Market-Driven Associated Storage
Competitive Process	C Standalone Storage Controlled by CENACE	D Associated Storage Controlled by CENACE

We will consider each of the scenarios A, B, C and D, in a following format:

	Investors (CFE & IPPs)	Society
Benefits	1 Benefits to CFE and IPPs	2 Benefits to Society
Disadvantages	3 Disadvantages for CFE and IPPs	4 Disadvantages to Society

It is possible to combine the two tables to describe the benefits and disadvantages for investors and society associated with cases A, B, C and D. After discussing each case we will consider regulatory changes necessary to make the considered case possible.

A) Market-Driven Standalone Storage

A1: Benefits to Investors

- Investor controls and administers the asset as she sees fit (if it is under 20 MW capacity).
- Investor can sell capacity and power and take advantage of the price arbitrage.

- Investor can offer ancillary services on the MEM, or to CENACE if they are not included in the MEM.

A2: Benefits to Society

- Primary benefits to society are the positive externalities that are not included in the price of the products storage offers, such as:
    - Potential decline in GHG emissions due to displacement of peaker plants and/or spinning reserves burning hydrocarbon fuels.
    - Decline in electricity prices due to peak-shaving, and decreased congestion.
    - Potential decrease in transmission tariff due to postponed or avoided transmission infrastructure investment.

A3: Disadvantages to Investors

- There are high investment costs without security of income associated with a long-term contract. The day-ahead market is volatile and presents a considerable risk.
- Investor pays transmission tariff twice (when charging, and when releasing energy).
- Investor has to buy energy on the market. She does not have the benefit of storing energy which would otherwise be curtailed.
- The price differentials between peak and low market prices might not be enough to pay for energy, losses associated with storage, the capital costs, and still provide a rate of return investors expect.

A4: Disadvantages to Society

- Possible environmental impacts, conditional on the type of storage technology.
- Many services offered by an investor decrease in price as the amount of the provided service increases. Consequently, a revenue-optimizing investor will not provide a socially optimum quantity of services (see Appendix B).

The regulatory modifications that could make this case possible include:

- Eliminating the Market Basis 6.2.5 which states that primary regulation (or frequency control) shall not be remunerated in the MEM, and modifying Market Basis 10.4.1 to add primary regulation to ancillary services included in the MEM (SENER, 2015).
- Defining a remuneration methodology for ancillary services not included in the MEM[32], and establishing a transparent procedure to offer those services to CENACE.
- Making a "Limited Energy Resource" classification voluntary for storage systems with capacity of 20 MW or higher would permit storage owner to dispatch the system as he or she sees fit, instead of having CENACE dispatch the system, since currently "Limited Energy Resources" are dispatched by CENACE (SENER, 2017). Having control of the storage system's dispatch would permit the storage owner to play the market and take advantage of price arbitrage opportunities. Nevertheless, it could be argued that

[32] The ancillary services not included in the MEM are: black start and connecting to the grid, voltage control, and operation in an "island mode"

making "limited energy" label voluntary would make managing the grid less predictable, more difficult, and therefore prone to operating problems.

- Capacity market only rewards storage with capacity below 20MW if it is operating during 100 critical hours (SENER, 2016b). Lowering that threshold could contribute to promoting investment in storage systems, because it would permit storage systems to sell "availability", thus providing another source of revenue, instead of being rewarded only if the plant is actually generating in those critical hours

Although above regulation modifications would theoretically promote investment into standalone storage, practically this investment would be very unlikely to happen. That is because standalone storage would compete with associated storage that would have potentially cheaper electricity (by possibility of storing "free" electricity which otherwise would be curtailed by CENACE), and cheaper transmission costs (30% when the stored energy is injected into the system, compared to 100% for standalone storage).

At the time of writing this section, the Mexican electricity market did not have merchant plants, and a market-driven standalone storage is analogous to a merchant plant.

B) Market-Driven Associated Storage

B1: Benefits to Investors

- Investor controls and administers the asset as she sees fit (if it is under 20 MW capacity).
- Investor can sell capacity and power, and take advantage of the price arbitrage.
- Investor can store energy which would otherwise be curtailed.
- Investor pays only for injecting the electricity into the grid (provided that storage is only charged with electricity generated by the associated plant).
- Investor can offer ancillary services on the MEM, or to CENACE if they are not included in the MEM.
- Storage permits the associated plant to comply with frequency control requirements.

B2: Benefits to Society

- The positive externalities or benefits not included in the price of the products storage offers, are the same for associated storage as for standalone storage:
    - Potential decline in GHG emissions due to displacement of peaker plants and/or spinning reserves burning hydrocarbon fuels.
    - Decline in electricity prices due to peak-shaving, and decreased congestion.
    - Potential decrease in transmission tariff due to postponed or avoided transmission infrastructure investment.

B3: Disadvantages to Investors

- There are high investment costs without security of income associated with a long-term contract. The day-ahead market is volatile and presents a considerable risk.
- The price differentials between peak and low market prices might not be enough to justify the investment.

- The services storage offers are "cannibalistic" in their nature: the more of the service provided (energy during peak demand, congestion, etc.), the lower the price received for that service.

B4: Disadvantages to Society

- Possible environmental impacts, conditional on the type of storage technology.
- Many services offered by an investor decrease in price as the amount of the provided service increases. Consequently, a revenue-optimizing investor will not provide a socially optimum quantity of services (see Appendix B).
- There is a potential, especially in case of pumped hydro, to use electricity generated by hydrocarbon fuels to pump and store water and afterwards claim clean energy certificates for electricity generated with that water.

The regulatory modifications necessary to make this case possible include:

- Eliminating the Market Basis 6.2.5 which states that primary regulation (or frequency control) shall not be remunerated in the MEM, and modifying Market Basis 10.4.1 to add primary regulation to ancillary services included in the MEM (SENER, 2015).
- Defining a remuneration methodology for ancillary services not included in the MEM[33], and a establishing a procedure investors can follow to offer those services to CENACE.
- Making a "Limited Energy Resource" classification voluntary for storage systems with capacity of 20 MW or higher. Currently "Limited Energy Resources" are dispatched by CENACE (SENER, 2017)
- Capacity market only rewards storage with capacity below 20MW if it is operating during 100 critical hours (SENER, 2016b). Lowering or removing the threshold could contribute to promoting investment in storage systems. In California, to participate in the RA market (Resource Adequacy refers to capacity), storage has to provide energy for three consecutive hours, with a minimum capacity of 0.5MW.
- Adjust the permitting process to include storage in all relevant permits of associated plant, such as interconnection permit, environmental impact evaluation, etc.
- Decrease the threshold necessary to be considered a capacity supplier from six consecutive hours at full capacity (SENER, 2016b) 34, since it this creates an entry barrier for many storage technologies and favors pumped hydro.

An increasing number of renewable energy companies in Mexico are interested in electricity storage for a number of reasons:

- A storage system permits capturing energy that would otherwise be curtailed or "wasted", and permits energy arbitrage – not only with the curtailed energy.
- An associated storage system ensures compliance with frequency control obligations stated in Market Basis 6.2.5 (SENER, 2015).

Nevertheless, there is virtually no investment in storage in Mexico, principally due to the uncertain return on investment. An associated storage system can earn money either through

[33] The ancillary services not included in the MEM are: black start and connecting to the grid, voltage control, and operation in an "island mode"

[34] Manual de Balance de Potencia, 5.3.5 (d) iv

energy arbitrage, by selling capacity, or by selling ancillary services. Even if regulations were modified to fully embrace storage systems in accordance with the Market Basis 3.3.21, which states that "Generators can offer all products that storage equipment is capable of producing under the same terms as any other power plant" (SENER, 2015), the capital costs of storage may make the investment in storage unlikely without a long-term contract for the services storage can offer. The risk associated with the short-term market is generally too big to encourage investment[35]. To put things in perspective, it is important to note that power plant investments in Mexico are anchored by long-term purchase power agreements (PPA) either with the CFE, or industrial clients. A number of those plants have capacity that exceeds the PPA, which is used to market electricity either through bilateral contracts, or on merchant basis, but it is the PPA that provides the long-term revenue security.

The cost of some storage technologies, such as Li-ion batteries, has been significantly decreasing which might suggest that storage investment is likely to increase, as the technology become more cost-efficient. Some of the services offered by storage systems, such as voltage control, have characteristics of a natural monopoly where large fixed costs associated with storage preclude competition since usually one reasonable sized storage system would be enough to meet local voltage control requirements. Similarly, nodal congestion relief could also be addressed with a reasonably sized storage system, making the market too small to permit liquidity derived from competition. Consequently, the larger the storage capacity installed, the lower the revenue per unit of capacity, creating a natural limit with a first mover advantage. The more of storage there is, the cheaper is the price of the services it can offer. A market-driven storage will only happen if it can make profit for investors appropriate for the level of the risk involved.

One could argue that either the standalone or associated storage could obtain revenue security by making one of its value stacking components a long-term ancillary service contract, a capacity contract won at a long-term capacity auction, or a long-term frequency control contract similar to those in the UK described previously in Chapter I, where a response time of under one second would be required. This might elicit a different mode of storage participation: long term contracts obtained through competitive processes.

C) Standalone Storage Controlled by CENACE Classified as "Transmission"

C1: Benefits to Investors

- Investor is not exposed to market risks.
- Revenue security.
- Investor receives the rate of return that she was willing to accept in the competitive process.

C2: Benefits to Society

- The positive externalities mentioned in A2 and B2 are supplied at socially optimum levels.
- The system operator CENACE has a tool at its disposal to optimize the electric system.

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[35] There are few exceptions to that statement. For example, in Baja California Sur where significant price differentials between peak and low prices can create arbitrage opportunities, and Aura PV power plant was considering adding on a storage system.

- Classifying storage as transmission potentially lowers the electricity bill to consumers by decreasing the cost of transmission associated with storage (transmission doesn´t pay transmission) and by CENACE optimizing the system.
- Installing storage in isolated communities along with renewable generation might be a least-cost alternative to ensure economically disadvantaged groups receive electricity.

C3: Disadvantages to Investors

- Investor owns and operates the asset, but does not control it.

C4: Disadvantages to Society

- Possible environmental impacts, conditional on the type of storage technology.
- A long-term contract with a storage provider means that CENACE might not be able to take advantage of the latest storage technologies which might be cheaper and more efficient.
- Crowding out of private investment.

The principal regulatory modification necessary to make this case possible is elimination of Market Basis 3.3.21 which classifies storage as generation. According to the Electricity Industry Law Article (LIE) 3, XXVIII, (SENER, 2014), the electricity market participants are comprised of Generators, Marketers, Suppliers[36], Marketers who are not Suppliers, or Qualified Users. Classifying storage as “transmission” means that it would no longer participate in the MEM, but would still be part of the electric industry. The LIE’s Article 2 states that transmission is part of the electric industry and that it shall be owned and controlled by the State, which does not preclude contracts or associations with the private sector.

From a social point of view, this mode of storage system participation in the national system is arguably better than the other modes discussed so far, for a number of reasons.

First. Removing regulatory barriers to investment in electricity storage does not guarantee that the investment will take place on a desired scale. Corporate risk tolerance, corporate hurdle rate, alternative investment opportunities are just a few of many considerations that play into the final investment decision. The high cost of storage also means that investors require to recuperate significant amounts through electricity price arbitrage, selling capacity, or ancillary services; if that is not likely, neither is the investment. Society, on the other hand receives many benefits from storage that an investor cannot capture, such as GHG mitigation for example. Consequently, when CENACE or SENER procure storage, they will ensure socially optimum quantity of services is available, which will also imply increasing the quantity of positive externalities which have value to society.

Second. There is currently no mechanism that would promote externalities associated with storage. Currently CELs (Certificados de Energía Limpia) promote positive externalities associated with clean generation, while the Carbon Tax (CT) discourages negative externalities associated with fossil fuel generation. Both CELs and CT apply to generation, and electricity storage does not generate electricity. Consequently, it makes sense for the government either to create a market for the externalities associated with storage, or to procure socially optimum amount of services offered by storage which takes into account the value of externalities

[36] The term “Suppliers”, according to LIE, Art. 3 XLV (SENER, 2014), incorporates Qualified Suppliers, Basic Service Suppliers, and Suppliers of a Last Resort.

provided. Although it might be easier to quantify the value of deferred transmission infrastructure than increased energy independence, for example, it is important to consider the value of positive externalities when considering the costs of storage and the quantity to be procured.

Arguably, using CELs to foster electricity storage would be misguided. Assuming that clean generation received CELs corresponding to the amount of produced energy, granting CELs to storage facility for storing that energy would amount to double counting – even if the stored energy were used to replace generation from a contaminating peaker plant. A more appropriate method of sharing the externality benefits with the private sector would be through fiscal incentives and adjustments to tax law.

Third. Even if the proposed regulatory changes were enough to bring about private sector investment in storage, the amount of storage provided would be socially sub-optimal (see Appendix B). For example, a storage system providing congestion relief at a certain node is a natural monopoly. One storage system at that node can make a profit, but if another storage system would enter both would lose money. The "market" for that service is not large enough to accommodate competition. A storage system administrator knows that as the amount of electricity released from storage into the system increases, the price of electricity decreases. That is independent of how well a market is constructed, it is simply a consequence of large capital costs. In summary, an investor will behave in a way that optimizes its profits, and not necessarily social welfare.

The assumption that the private sector is most qualified to efficiently develop and operate electricity storage systems does not contradict the fact that CENACE should administer all the services that storage can offer to ensure socially optimal use of storage potential. Market structures that would make such an arrangement attractive to a private sector would be similar to PPA or BOT[37] style contracts – which have a proven track record of attracting private sector investment. They provide the long-term revenue anchor which market-driven standalone or associated storage systems do not have. In addition, they eliminate market risk and offer the desired rate of return for the winning bid (since that was the rate of return included, though usually not disclosed, in the bid package).

The positive externalities of storage previously mentioned benefit the population at large, so it stands to reason that they should be paid for by the population at large as well, through a regulated transmission tariff.

It could be argued that storage systems should be classified as a transmission asset, since most of the services storage offers benefit transmission: voltage control, frequency control, congestion relief, or avoidance of transmission infrastructure investment, etc. However, this does not mean that CFE Transmission must acquire storage. The Article II of LIE, which permits the government to make associations with the private sector, includes SENER. The reason why SENER might engage the private sector directly through competitive auctions, and not through CFE Transmission, is to free the CFE budget from projects it is not directly involved with. Alternatively, CFE Transmission could make an investment in storage.

Classifying electricity storage as Transmission is not intuitively obvious, but it has some advantages in context of the Mexican regulatory framework. In addition to all the benefits already mentioned, it is an option that arguably requires the least amount of regulatory adjustments. Also, it is probably an option that could benefit CFE the most. Currently, CFE

[37] BOT = Build, Operate, Transfer

assumes the cost of solving the challenges caused by intermittency and ramping associated with renewable generation. Storage administered by CENACE would solve those problems, without the cost to CFE. If CFE Transmission were to invest in energy storage, not only would the ramping and intermittency problem be solved, but CFE Transmission would earn a regulated return on its assets through a transmission tariff, at a minimal risk.

One of the negative side effects of standalone storage run by CENACE is the crowding out of market-driven investment. Supposing that CENACE will use socially optimum volume of services, the resulting market prices for those services might not be attractive enough to accommodate additional private sector investment. Finally, it is important to create regulations which will ensure that if CENACE were operating a storage system, it do so in a way that maximizes social benefit. For example, a regulation could obligate CENACE to only charge storage systems with renewable energy, accompanied by a regulation that obliges CENACE to pay a reasonable price for renewable energy even if it were to be curtailed. This would ensure optimum environmental impact by displacing traditional fossil fuel generation, it would promote investment in additional renewable generation by creating minimum prices, and it would minimize CENACE's incentives to create artificial conditions for curtailment.

D) Associated Storage Controlled by CENACE

An associated storage contracted through an auction would be a tolling agreement which would be in many ways similar to standalone option financed through transmission tariffs described above (C). However, there are at least two differences:

1. The standalone option is more flexible in terms of location whereas associated option is limited to locations with existing plants. On the positive side, if a storage system is installed on plant's property, risks associated with rights of way are avoided.
2. A standalone storage could be charged by any plant. However, if storage is associated with a particular plant, it is likely to be charged only by that plant – if anything, to avoid transmission losses. This could be perceived as favorable treatment of the associated plant by CENACE.

This suggests that the C) option might be the preferred among all considered options. However, there is another option worth mentioning. Not because it is a particularly good option from a social perspective, but because it might be of interest to investors. This option involves an investor offering a long-term contract for a specific service, frequency control for example, to CENACE. The contract would finance the storage asset and would remunerate the service when used. This contract is attractive to an investor, because it would finance the asset which could be used for price arbitrage, or to offer other services on the market or directly to CENACE, such as voltage control for instance. It is not socially attractive option because the contract in essence finances the asset for investor's use and benefit. It is more socially beneficial to acquire entire capacity and all services an asset can offer.

Vesting Contracts (Contratos Legados) and Pumped Hydro Storage

The SENER authored the vesting contracts, and is in a position to update them to encourage pumped hydro storage. Specifically, creating a higher rate of return for assets associated with storage, and permitting contract modifications analogous to a tolling agreement, SENER could acquire pumped storage capacity.

5. Alternative Regulatory Frameworks

In contrast to the previous section, this section offers a fresh approach - not constrained by the existing law - on how to modify the legal framework to optimize deployment and integration of storage within the grid.

5.1 A Storage Asset Class

A first modification could consist of creating a new asset class called "electricity storage", thus liberating the regulator and market participants from trying to accommodate storage characteristics within conventional generation framework. This would permit auctions for the new asset class without coupling it with other asset classes such as transmission, generation, or marketing.

The principal benefit of creating a new asset class is a recognition of distinct characteristics associated with storage. For example, an auction for an array of services that storage could offer, including fast frequency response, could be held for a new asset class, taking into account storage limitations in terms of time. If storage is forced to compete with conventional generation for provision of services where the duration of provision of those services is not specified, or is longer than average storage systems can provide, storage will have to recover its investment only through services where it has clear competitive advantage, such as fast frequency response, making them more expensive than they could be otherwise if offered a part of a set of services. This would not only promote storage investment, but would foster the positive externalities associated with storage, such as potential mitigation of greenhouse gases.

Recognition of a storage asset class would also eliminate certain barriers dissemination of storage. For example, in Mexico the cost of transmission is recuperated through a tariff that is levied on generators and the load. A generator that produced a MWh of energy that was stored paid a transmission tariff, and the final consumer who received that MWh after it was released from storage also paid a transmission tariff. Consequently, transmission recuperated its costs associated with transporting that MWh of energy, and there is no need to levy a transmission tariff on storage, much less twice: while charging and discharging. This would be true if there were no storage losses. The load does not receive the energy lost in storage, and therefore does not pay transmission tariff associated with that energy. That shortfall in transmission income could be recuperated through a transmission tariff levied on storage losses. A transmission tariff specifically for storage asset class on energy losses associated with storage.

5.2 Integration of Storage Systems

A second modification of the legal framework could focus on the integration of storage systems within the grid. This integration could take place through a combination of favorable market regulation, which encourages storage systems, similar to the UK, and obligation resembling

California. The UK, for example, created a market for a service that by and large only storage can offer, such as Enhanced Frequency Response, which requires release of active power in one second or less once a deviation from required frequency is registered. While the UK promoted deployment of storage through a market structure, California made it a regulatory obligation for load serving entities to acquire storage capacity as early as 2010, through an Assembly Bill 2514. The bill facilitated a contractual relationship between load serving entities and storage operators, which generated revenue security for storage, and which served as an anchor for the storage systems entering the market. This type of anchor is necessary because a high penetration of storage systems is likely to result in levelized electricity prices making it very difficult to earn money through arbitrage.

The fiscal law could also be modified to permit accelerated deductions for the storage asset class, similarly to renewable assets. The amount of fiscal stimulus could be commensurate with the value of principal positive externalities associated with storage.

Integration of electricity storage systems into the grid would also require the appropriate modelling of storage dispatch in order to optimize system operations. Generally, a dispatch merit order for conventional generation is based on cost of producing energy. In case of storage, the dispatch decision would not only depend on the market cost of energy when it was stored, but on the opportunity cost of releasing it, and the time required to recharge it to make it available again. The opportunity cost of releasing energy from storage is not being able to release afterwards (at least for the duration of recharging).

The concepts behind the presented alternative regulatory framework are derived from observed areas of opportunity in the existing Mexican regulation as well as regulations that have worked well (or not) in the UK and the US markets and could be adopted (or avoided) in the Mexican market.

The regulatory frameworks around the world pertaining to electricity storage are best described as work in progress. Energy storage regulation is relatively new, and is still in the process of being formulated or modified almost everywhere in the world. Although regulatory and market challenges associated with energy storage are similar, the proposed solutions to those challenges differ across different jurisdictions.

5.3 International Examples

In Denmark the sudden increase in rooftop solar in 2012, initiated risk of a parallel boom in small-scale energy storage. The risk of unregulated energy storage triggered creation of technical regulation for batteries, with the focus on system stability requirements. The regulation, not only articulates technical connection requirements for batteries, but also permits tracking storage capacity within the system in order to make authorities aware of the development and hence able to react upon it. The first published Technical Requirements considered only batteries and was developed rather quick and dirty in 2017. Then a more comprehensive Technical Requirement was developed and published in 2019 which considered all energy storage except in electric vehicles. Europe is now following in Denmark's footsteps and is evaluating network codes similar to what Denmark has implemented.

Future steps towards better integration of storage in the market is currently considered in both Denmark and Europe for example, lowering the minimum bid sizes, lowering the market gate closure, decreasing imbalance settlement periods and increased marketization of ancillary services are all being considered which could foster energy storage participation in the electricity market.

The European Directive 2019/944 "establishes common rules for the generation, transmission, distribution, energy storage and supply of electricity, together with consumer protection provisions, with a view to creating truly integrated competitive, consumer- centered, flexible, fair and transparent electricity markets in the Union" (EU, 2019).

The Directive states that " 'fully integrated network components' means network components that are integrated in the transmission or distribution system, including storage facilities, and that are used for the sole purpose of ensuring a secure and reliable operation of the transmission or distribution system, and not for balancing or congestion management" (EU, 2019)[38].

The European Union has taken a market approach to implementing storage, similarly to the UK experience already described. Specifically, the directive states that "System operators should not own, develop, manage or operate energy storage facilities. In the new electricity market design, energy storage services should be market-based and competitive. Consequently, cross-subsidization between energy storage and the regulated functions of distribution or transmission should be avoided.[39]" It goes on to say how storage providers should be given every opportunity to provide their services.

The market approach to integrating storage into the electricity system presents numerous challenges for the Mexican market. The European market is moving to decentralized generation and systems, in significant part propelled by distributed generation, which for socioeconomic reasons is not likely to happen in Mexico at similar extents on the level of residential consumers. Also, it is important to realize that storage is a new technology to which regulations are trying to catch up across the globe. Some markets, such as Europe, are using a market-based approach to integrate energy storage into their electricity systems. Other markets, such as California, are integrating storage through regulatory requirements. There is no track record to suggest that what Europe is doing is successful, and an example of shortcoming associated with integrating storage solely through market commercialization can be observed in UK. Likewise, shortcomings of integrating storage solely through regulation which made storage compulsory can be seen in California experience. The fact is that integration of storage systems into electric grids is a work in progress, and Mexico is no exception.

6. Conclusions

The growing interest in energy storage in Mexico has precipitated a series of workshops and conferences with participation of the academia, government agencies, and the private sector, focused on potential role storage can play in the national electric grid. One of the conclusions common to all the workshops was that the current regulatory framework is not conducive to investment in energy storage. Some of the principal barriers to storage include lack of market for fast frequency response, which is the principal manner storage systems participate in

[38] Definition #51, Directive 2019/944 of the European Parliament

[39] Subject Matter #62, Directive 2019/944 of the European Parliament

electricity markets around the world, lack of long-term contractual framework which could encourage investment by providing revenue security, and absence of a formal procedure for procurement of ancillary services not included in the wholesale market.

Most of the suggested modifications to overcome barriers to storage were made at a regulatory level, under CRE's jurisdiction, thus circumventing the necessity of changing the LIE. The proposed changes concentrated on stimulating private sector investment in storage by making it possible for storage to market all services it is able to provide. A different avenue of overcoming barriers to storage includes classifying storage as transmission, and procuring storage capacity through long-term contracts similar to power purchase agreements.

Electricity storage, aside from commercial benefits, provides an array of social benefits which are not captured in the price of services storage can provide. If the value of the services provided by storage, combined with the value of positive externalities exceeds the cost of storage, then from the social perspective storage should be encouraged.

7. References

Congreso de la Unión. Decreto por el que se reforman adicionan diversas disposiciones de la Constitución Política de los Estados Unidos Mexianos, en Materia de Energía (2013). Retrieved from: http://www.dof.gob.mx/nota_detalle.php?codigo=5327463&fecha=20/12/2013

Congreso de la Unión. Ley de la Industria Eléctrica (2014). Retrieved from http://www.dof.gob.mx/nota_detalle.php?codigo=5355986&fecha=11/08/2014

El Congreso General de la Unión (2015), La Ley de Transición Energética. Retrieved from: http://dof.gob.mx/nota_detalle.php?codigo=5421295&fecha=24/12/2015

Secretaría de Energía (SENER) 2015, Las Bases del Mercado Eléctrico. Retrieved from: http://www.dof.gob.mx/nota_detalle.php?codigo=5407715&fecha=08/09/2015

Secretaría de Energía (SENER) 2016-2019, Manuales de Prácticas de Mercado. Retrieved from: https://www.cenace.gob.mx/Paginas/Publicas/MercadoOperacion/ManualesMercado.aspx

Secretaría de Energía (SENER) 2017, Manual de Costos de Oportunidad. Retrieved from: http://www.dof.gob.mx/nota_detalle.php?codigo=5501341&fecha=16/10/2017

Secretaría de Energía (SENER) 2016a, Manual de Mercado de Energía de Corto Plazo. Retrieved from: http://www.dof.gob.mx/nota_detalle.php?codigo=5441705&fecha=17/06/2016

Secretaría de Energía (SENER) 2016b, Manual del Mercado para el Balance de Potencia. Retrieved from: http://dof.gob.mx/nota_detalle.php?codigo=5453483&fecha=22/09/2016

Secretaría de Energía (SENER) 2016c, Manual de Registro y Acreditación de Participantes del Mercado. Retrieved from: http://www.dof.gob.mx/nota_detalle.php?codigo=5444865&fecha=15/07/2016

Secretaría de Energía (SENER) 2016d, Minuta de Sesión Grupo de Trabajo de Almacenamiento de Energía Consejo Consultivo de la Transición Energética. Retrieved from: https://www.gob.mx/cms/uploads/attachment/file/118013/Minuta_1a_Sesi_n.pdf

Secretaría de Energía (SENER) 2016e, Minuta de la Segunda Sesión Grupo de Trabajo de Almacenamiento de Energía Consejo Consultivo de la Transición Energética. Retrieved from: https://www.gob.mx/cms/uploads/attachment/file/118017/Minuta_2a_Sesi_n.pdf

Secretaría de Energía (SENER) 2016f, Minuta de la Tercera Sesión Grupo de Trabajo de Almacenamiento de Energía Consejo Consultivo de la Transición Energética. Retrieved from: https://www.gob.mx/cms/uploads/attachment/file/118020/Minuta_3a_Sesi_n.pdf

Instituto Nacional de Electricidad y Energías Limpias (INEEL), 2018, Reporte de Prioridades Nacionales Sobre el Tema: "Almacenamiento de Energía en la Red Eléctrica"

Gauss Energía S.A. de C.V.& Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) Electrical Energy Storage in Mexico (2019). Retreived from: https://www.bivica.org/files/5368_almacenamiento-energia_Mexico.pdf

Secretaría de Energía (SENER) 2019, Programa de Desarrollo del Sistema Eléctrico Nacional 2019-2033 (2019). Retrieved from: https://www.gob.mx/sener/documentos/prodesen-2019-2033

Secretaría de Energía (SENER) Y Comisión Nacional para el Uso Eficiente de la Energía (CONUEE) 2016g. Estrategia de Transición para Promover el Uso de Tecnologías y Combustibles Más Limpios. Retrieved from: https://www.gob.mx/cms/uploads/attachment/file/182202/20161110_1300h_Estrategia_CCTE-1.pdf

European Parliament and the Council (EU) 2019, Directive 2019/944 of the European Parliament and the Council of 5 June 2019 on common rules for the inernal market for electricity and amending Directive 2012/27EU. Retrieved from: http://www.legislation.gov.uk/eudr/2019/944/contents

Secretaría de Energía (SENER) 2017a, Nota Explicativa Contratos Legados, Retrieved from: https://www.gob.mx/cms/uploads/attachment/file/258356/Nota_explicativa_contratos_legados.pdf

Secretaría de Energía (SENER) 2017b, Metodología, Criterios y Términos para Contratos Legados, Retrieved from: https://www.gob.mx/cms/uploads/attachment/file/258363/ANEXO_D.pdf

Centro Nacional de Control de Energía (CENACE), 2020, Pronósticos de Horas Críticas, Retrieved from: https://www.cenace.gob.mx/Paginas/Publicas/MercadoOperacion/PronHorasCriticas.aspx

Congreso de la Unión. Ley Del Impuesto Sobre la Renta (2019). Retrieved from: http://www.diputados.gob.mx/LeyesBiblio/pdf/LISR_091219.pdf

Secretaría de Energía (SENER) 2020, la Estrategia de Transición para Promover el Uso de Tecnologías y Combustibles más Limpios. Retrieved from: http:// http://dof.gob.mx/nota_detalle.php?codigo=5585823&fecha=07/02/2020

Secretaría de Energía (SENER) 2020, ACUERDO por el que la Secretaría de Energía aprueba y publica la actualización de la Estrategia de Transición para Promover el Uso de Tecnologías y Combustibles más Limpios, en términos de la Ley de Transición Energética. Retrieved from: https://www.dof.gob.mx/nota_detalle.php?codigo=5585823&fecha=07/02/2020