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Comparative analysis of Mexico's independent system operator with U.S. peers: Institutional assessment structures and performance metrics

Análisis comparativo del operador independiente del sistema eléctrico frente a sus contrapartes de EEUU: estructuras de evaluación y mediciones de desempeño

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Abstract

Wholesale electricity market assessment frameworks from the US provide a useful perspective for Mexico's new electricity market. First, an institutional economics analysis of strengths and weaknesses of Mexico's ISO (CENACE) provides a foundation for market assessment. Then, assessment frameworks used by US regulators studied herein for wholesale market operators highlight a framework for minimum necessary characteristics of electricity market products for application in Mexico's wholesale market. Such institutional frameworks could serve as future performance measures in CENACE, independent of the electricity policy model.

JEL code: L94, L15, Q48
Keywords: ISO/ RTO; ISO performance metric; Wholesale electricity markets; Minimum requirements

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Resumen

El estudio del marco de evaluación del Mercado eléctrico mayorista de los Estados Unidos ofrece una perspectiva útil para el nuevo mercado de México. En primer lugar, se realiza un análisis de economía institucional de fuerzas y debilidades del operador del mercado mayorista en México (CENACE), el cual provee los fundamentos para la evaluación del mercado. Posteriormente, los marcos institucionales de evaluación observados en los Estados Unidos analizados en el presente trabajo, sirven de guía para establecer los aún no implantados "requerimientos mínimos" de los productos del mercado mayorista en México para el que el operador CENACE cuantifique su desempeño, independientemente del modelo de política eléctrica.

Código JEL: L94, L15, Q48
Palabras clave: Operador independiente del sistema; Medidas de desempeño; Mercado eléctrico mayorista; Requerimientos mínimos

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Introduction

Mexico's energy marketplace is undergoing transformation due in part to electricity market restructuring and rapid adoption of renewable energy. Mexico's 2014 Energy Reform includes incumbent electricity utility unbundling along with the creation of a market-clearing independent system operator (ISO) called CENACE (Centro Nacional de Control de Energía)[1]. The Reform is a foundation for wholesale markets in energy, capacity, ancillary services, and financial transmission rights (FTRs). It also includes a clean energy certificate program similar to renewable energy credit programs that exist in many U.S. states.

Wholesale electricity markets—like the market CENACE operates in Mexico — are composed of multiple sub-markets, such as day-ahead energy and spot energy markets. In addition to these markets, there are short-term balancing and long-term instruments such as yearly and up-to three-year capacity markets. A market for yearly and multi-year FTRs exists as well. Clean energy certificates were purchased in three energy auctions led by CENACE from 2016 to 2017. The López-Obrador administration cancelled the fourth auction, which was slated for 2019, and did not indicate an interest in further auctions in the near term (García 2019).

[1] The Mexican Law of the Electrical Industry (Ley de la Industria Eléctrica), in Chapter II, Arts. 107-112, established that CENACE would become an independent public organization, with juridical independence and its own funding. Stated objectives included that it: a) be the operative control of the national electrical system (SEN); b) be the locus of all operations of the electricity wholesale market; c) guarantee open access with no undue discrimination to the national transmission and distribution networks, among the ones spelled out in the Law (Art. 107); and d) guarantee the operation of all the system with parameters of efficiency, quality, reliability, continuity, security, and sustainability (Art. 109). Subsequently, CENACE was administratively established by a decree published on August 28, 2014, in the National Gazette.

Perhaps unsurprisingly for such a complex system of interrelated markets and regulatory programs, restructured markets across the world exhibit evidence of both regulatory and market failure. These market and regulatory failures result in part from factors such as imperfect information, lags in regulatory compacts that result in uncertainty for investors, a slow pace of new energy mix adoption, and industry market power games (Ibarra-Yunez, 2015; Joskow, 2006; Majone, 2005; Quintyn, 2007). Given these trends, and Mexico's relatively nascent electricity market, "metrics" for evaluating the depth of ISO engagement and development can serve as a helpful tool for measuring success moving forward. An overview of ISO evaluation metrics and their application to Mexico's emerging electricity market are the central focus of this research. The bottom line in the analysis is that if a wholesale market clearing institution lacks the means to measure market performance at all levels, then it may jeopardize the viability of the market it seeks to facilitate and coordinate. This "minimum functions" framework is explored in-depth in this contribution.

Mechanisms intended to enhance market activity and development have seen mixed success since the Mexican electricity sector began restructuring in 2014. Mexico's wholesale market faces significant challenges related to market concentration as the formerly vertically integrated state-run electric utility, Comisión Federal de Electricidad (CFE) undergoes restructuring. Challenges associated with market concentration have been prevalent in similar electricity reforms in the UK and Europe (Bielecki & Desta, 2004), as well as in ERCOT and PJM in the United States (Pollitt, 2012). Mexico has strived to meet to the central goals and timeline of the Energy Reform in the medium term. If it is successful in doing so, its wholesale market will likely benefit from overall cost reductions and transparency improvements associated with reduced market concentration and greater investor confidence (Chanona Robles, 2016, pp. 16, 32).

In November 2017, large-scale renewable electricity procurement auctions in Mexico yielded average prices of USD $21 per megawatt hour, among the lowest prices ever recorded in similar auctions in Latin America (Davis and Irastorza, 2017). Beyond anticipated renewables growth due to low prices, intermittent renewable energy sources are likely to increase on Mexico's grid due to national policy objectives. Among these are the nationwide mandate for all large electricity consumers, and basic service electricity providers, to obtain 35% their total electricity consumption from renewable and clean sources by 2024. In order for Mexico to harness the full potential of this renewable generation, its market frameworks must evolve. For example, intermittent renewables like wind and solar benefit from grid characteristics such as flexibility and robust ancillary services markets (Anaya and Pollitt, 2016, p. 73). One way for CENACE to help Mexico maximize the benefits of this low-cost renewable energy is by opening ancillary service markets with clear associated market product definitions, which have the potential to hasten market entry and increase participation (Cochran et al., 2013, p. vi).

Mexican wholesale market operators have an opportunity to apply market metrics from US peer institutions to assess their own progress. Metrics based on the US experience can be useful for Mexico's evaluation of the status of post-reform market concentration. They are also applicable tools for measuring ancillary services market development. To demonstrate how this self-assessment could be carried out in Mexico, this research applies a framework that the US Federal Energy Regulatory Commission (FERC) uses to assess "minimum functions" or characteristics of U.S. wholesale electricity markets and their respective ancillary services submarkets.

The analytical approach begins with an institutional assessment of strengths and weaknesses of CENACE and provides an initial framework for continued market assessment. The analysis then uses a cross-evaluation of CENACE's evolution with FERC's "minimum ISO/RTO functions" to highlight the importance of continued market development in Mexico. The paper is organized as follows: Section 2 is an institutional assessment of ISOs that summarizes FERC's "minimum functions" (FERC, 1999) and market evaluation metrics (FERC, 2010) in the context of CENACE. Section 3 applies these minimum functions as metrics for CENACE and identifies strengths and weaknesses. Section 4 concludes.

Institutional assessments of ISOs

Institutional Economics provides an applicable framework to evaluate market-clearing ISOs in transitional markets. For example, Coen and Thatcher (2008) establish the framework for governance in networks of regulators. Srivastava et al. (2011) spell out alternative ISO designs and their strengths and weaknesses, while Jamasb and Pollitt (2005) and Pollitt (2008, 2012) create a minimum set of ISO institutional endowments to analyze an ISOs various alternative institutional and functional attributes. Still others have applied laboratory experiments to the economics of policy design in electricity markets (Griffin and Puller 2009), while Rudnick and Velasquez (2018) review various cases of transition power markets in terms of their strengths and weaknesses.

Vertical unbundling of the incumbent monopoly utility gives rise to various market organizational alternatives, but a wholesale market operation is key to effective implementation regardless (see, for example, Joskow 2000, 2006; Joskow and Kahn 2001, Kwoka 2008, Pollitt 2008). The literature suggests that strengths or weaknesses in ISO operation of the wholesale market are relevant for addressing an array of challenging areas across electricity markets, for example in the case of energy storage in wholesale markets in the US (Sakti et al., 2018).

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Institutional analysis of ISOs can be applied from numerous angles and approaches. For example, analysis can focus on how price data are issued, how local marginal costs are calculated, and how software facilitates user decision-making (e.g., industrial consumers). Further, analyses can address open season readiness, degree of gas market available for electricity generation and/or primary energy, and the degree to which bilateral trade agreements may restrict the deepening of an ISO market. Other examples include exploring ways that energy hubs deal with an excess of nodes and researching differences between financial versus physical markets. To provide a concrete example from a similarly regulated industry, Klemperer (2001) explores auction winner liquidity in the telecommunication industry in a low project price environment.

For their part, Gugler et al. (2017) studied the lost synergies of vertical disintegration, while Milligan et al. (2016) concentrated on calculating revenue sufficiency and reliability when a deregulated market aims to increase renewable and behind-the-meter incentives for "prosumers." The considerations outlined in this literature review are just some of the many that CENACE currently faces as its wholesale marketplace takes shape and it adds complexity to structures that support and enhance market effectiveness. The following section turns to assessment of CENACE's early stage of development to identify key areas that the ISO can focus on and enhance as it moves into its fifth year of operation under an administration that appears to be reemphasizing the role of government across the Mexican electricity sector (Wood, 2019).

CENACE's Evolution and Wholesale Market Auctions

CENACE was originally part of the incumbent, vertically integrated, state-run utility Comisión Federal de Electricidad (CFE). Prior to the Energy Reform, CENACE operated a virtual market for energy and capacity to efficiently allocate loads as per the former law (Ley del Servicio Público de Energía Eléctrica, LSPEE, 2013) that allowed private generation for approximately 830 permits mostly for self-supply, and co-generation. So-called independent power producers or PIEs in Mexico's definition, accounted for around 65% of the national energy in 2014, that was to be sold exclusively to CFE (CRE, 2017). The Energy Reform made CENACE a decentralized public organization in August 2014 and reorganized it into an ISO with varying levels of what FERC has dubbed "minimum [ISO/RTO] functions". CENACE's wholesale market began operating in February 2016 with step-wise implementation of different sub-markets and products, from which short term (day ahead and then real time) energy submarkets were first implemented. These were followed by long term renewable auctions, capacity markets and then second and third rounds of renewable auctions (CENACE

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2015). Parts of the originally scheduled sub-market implementation have not kept up with the original timeline.

As of mid-2018, 38 private generators participate in the wholesale market. 27 of these generators are qualified suppliers and 10 generators are registered as traders without investments in generation for supply to the market (CENACE 2019). CFE Básicos subsidiary, an organization created as part of the unbundling of the national utility, serves as a basic service and intermediate supplier.

Perspective from the U.S. experience is helpful for understanding the evolution of Mexico's electricity market. The U.S. is home to seven different ISO/RTOs, with a diverse range of experience that date back to the mid-1990s. The diversity and extent of the U.S. experience in wholesale market design and regulation is very detailed and offers many layers of sub-markets and products. This makes for fertile ground for comparative analysis with Mexico. The analysis could also address other world markets such as in Europe or Australasia. However, the present approach is justified given the proximity of Mexico and US markets, as well as the data availability and its evolution for yearly evaluation and adaptation. Now, one key piece of regulation in the US, FERC Order No. 2000, asserts that the electrical system can ensure quality, reliability, continuity, security, and sustainability through market-driven activities. Mexico's objectives for electricity market restructuring are relatively well aligned with these in that they include a) separation of monopoly parts from competitive parts by unbundling of generation, transmission, distribution, load, trade, and retail at various levels; b) promotion of competition through third-party access rules, non-discrimination of access by transmission and distribution grid subsidiaries, and increasing entry to the wholesale markets; c) ensuring that new markets with many participants will not fail in reliability, security of supply, and sufficient energy; d) seeking to align prices through market forces rather than by way of regulation, except in the case of regulated services; and e) transparency in all aspects of the new market dynamics.

CENACE has a legal obligation to a) enhance and deepen the wholesale market operations of all products traded; b) guarantee energy, physical requirements of efficiency, quality, reliability, continuity, security, and sustainability; and c) guarantee open access with no undue discrimination to the national transmission and distribution networks of all participants from the supply and demand sides of the market, in accordance with the Mexican Electricity Industry Law, or LIE (2014) and CENACE's founding documents (CENACE, 2015).

Mexico's wholesale market began operation in February 2016. CFE load centers were the first to enter the market. CFE also participated in the first auctions for solar and wind energy in March 2016. In June 2016, the second auction attracted the first private investors in generation—24 new clean generating facilities entered the market with funds from Mexican and

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international investors. Per Mexico's Secretary of Energy, SENER, clean generation is defined as electricity produced by hydroelectric, nuclear, wind, solar, highly efficient combined cycle natural gas, geothermal, and biomass facilities. According to CRE presentations in 2017, 52 new generating facilities were expected between 2018 and 2020, representing 5 gigawatts of additional capacity. 38 were operating as of mid-2018. Table 1 outlines the distribution of market participants as of 2018.

As shown in Table 1, CRE (Mexico's national energy regulator) has granted many more permits for generators than there are market participation permits in CENACE. Among these, CRE has registered numerous solar, wind and hydroelectric projects, but no information is available on them in CENACE's platform. The renewables projects registered with CRE mainly serve CFE load centers. Moreover, as of 2018, CENACE has 76 registered generation projects, while there are 285 wind, solar and hydroelectric permits in CRE's official registry (CRE, 2018). The fact that generation projects fail to appear in CENACE's contracts list well after auctions took place in 2017 may imply time asymmetries in launching renewable generation for the wholesale market, or administrative problems at the wholesale market level that have delayed investment in projects.

Table 1

Participants in Mexico's Short-term Market, 2018

	CRE permit holders (2018)	With CENACE market participant contract
Generators	1283	76
Renewable permits before and after Aug 11, 2014	122 (before new law) 229 (after new law)	Not applicable Not specified
Hydroelectric generation permits before and after Aug 11, 2014	47 (before new law) 56 (after new law)	Not applicable Not specified
Basic service supply	2	2
Qualified facility suppliers	43	43
Traders with no facilities	17	17
Qualified users	84 (represent 1,349 load centers)	25 (represent 941 load centers)

Source: CENACE, 2018: Participantes del Mercado con Contrato (market participants with contract), December. 2018. CRE, 2018 Permisos de Electricidad (electricity permits), March 2018. Sistema de Información Energética (SIE), 2017. Note: SIE's data ends in 2017 and data set has not been updated at the date of the present analysis.

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Increasing Renewables and Potential Reliability Concerns

The significant addition of solar and wind capacity creates at once a challenge and an opportunity for CENACE. As of October 2017, 2.27% of Mexico's effective capacity came from non-hydro renewable sources (SIE, 2017). Beginning in 2018, supply-side participants (i.e., basic and qualified users) had to acquire 5% of electrical energy through the purchase of Clean Energy Certificates (CELs). Hydroelectric, nuclear, wind, solar, combined cycle natural gas, geothermal, and biomass facilities generate these CELs and can sell them to other consumers or, in the case of prosumers, use them to cover their own CEL obligations (SENER, 2017).[2] The required purchase of CELs will steadily climb to 35% by 2024, and non-compliance will result in per-MWh penalties (KPMG, 2016, p. 13). Pollitt and Ananya (2016) posit that "very few current market arrangements are set up to support high shares of renewable electricity at politically acceptable prices and levels of security and supply" (p. 74). As a relatively new wholesale market operator, CENACE's challenge is to shape the early development of its wholesale market products, especially as pertains to defining its ancillary services in such a way that they support renewable uptake and maximize utilization.

CENACE's Strategic Plan

CENACE's 2017-2021 strategic plan defines eight regional administrative branches, with one additional CENACE alternative office in the city of Puebla (CENACE, 2017). Their key functions include a) operating the national electric system efficiently and reliably; b) implementing and operating the wholesale market with open access to market participants with no undue discrimination to participants; c) proposing grid expansion (transmission and distribution); and d) internally development of human capital. The López-Obrador administration scrutinized and revised the strategic plan in early 2019 but has not released details and the rationale for the revision. The administration's website has reduced transparency in disclosing strategy or impending decisions (Martín Culell, 2019), and the administration is in the process of replacing regulatory posts with new personnel as of early 2019 (León, 2019). The 2017-2021 strategic plan did not mention promotion of

competition and an increased market participant pool, promotion of products in the wholesale market, promotion of market signals, a code of transparency, nor attracting stakeholders. The strategic plan process does, however, outline operational strategies and tactics (CENACE, 2017).

[2] CELs are similar to renewable energy credits (also known as RECs) in U.S. markets, but in most U.S. REC programs, nuclear and combined cycle natural gas are not eligible for credit generation.

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The 2017-2021 strategic plan's lack of emphasis on promotion of wholesale market products represents a lost opportunity to increase renewable participation in ancillary service wholesale market products. For example, research from 2014 on renewables curtailment under a 50% renewable generation scenario in California found that enabling renewables to provide operating reserve ancillary services reduced curtailment of renewables and had the potential to improve overall market economics during certain times of the year (Nelson and Wisland, 2015). The strategic plan's noted interest in development of metrics and measurements provides an opportunity for shared learning around co-development of renewables and ancillary service products in the U.S. The following section reviews how FERC and U.S. ISOs developed performance assessment structures and defined metrics in the first ten years of RTO/ISO development. FERC's "minimum functions" of an RTO/ISO (defined in 1999) are outlined below in the context of CENACE's first and second years of operation. Following FERC's minimum functions are 15 more granular metrics and measures of ISO/RTO performance that have since been developed by FERC.

FERC's minimum functions approach

Contrasting Minimum Functions with Market-driven Aims in Mexico

In December 1999, FERC defined the minimum functions of an RTO in Docket No. RM99-2-000, Order No. 2000. FERC based these minimum functions on lessons learned by the regulatory agency since FERC Order No. 888 provided a basis for the first U.S. RTOs in 1996. In Table 2, FERC's minimum functions are applied in the context of Mexico's CENACE as a basis for evaluating the system operator's development to date, as an exercise. These RTO/ISO minimum functions are listed and defined in the first two columns, and examples of their strengths and weaknesses are evaluated in the following columns.

Table 2

Minimum Functions and CENACE's Strengths and Weaknesses 2016-2018

Minimum Function	Minimum Function Definition	CENACE Strengths	CENACE Weaknesses
Tariff administration and design of wholesale prices	In the interest of reliability, efficient prices for transmission asset access and related markets are implemented.	CENACE has set day-ahead and real-time tariffs, including for imbalance and capacity markets.	Wholesale market FTRs are only applicable to CFE, the incumbent electric utility.
Minimum Function	Minimum Function Definition	CENACE Strengths	CENACE Weaknesses
Grid expansion	ISO coordinates and evaluates future investment in transmission network.	The ISO has rules in place for OPEX/CAPEX and private subcontracting of transmission/distribution operation.	CENACE has not established a clear, long-term vision for grid expansion and access to new energy sources (e.g., renewables).
Interregional coordination of control areas and nodes (nodal management)	The ISO, in conjunction with other ISOs, manages flows of electricity across multiple control areas and internationally.	CENACE is currently engaged in this level of interregional management in 49 of Mexico's 51 control areas. The two areas where this is not taking place are Baja California and Baja California Sur.	CENACE's integration of Baja California and Baja California Sur into the national grid is still pending.
Pace and momentum	The authors added this metric because FERC's list does not adequately capture the importance of pace and momentum in the transition away from a vertically integrated, national incumbent electric utility in the context of a developing economy.	In line with the timeline established under Mexico's Energy Reform, day-ahead and real-time markets are operational. Medium-term contracts are also in place.	Only a small fraction of total permit holders participated in the market at the end of 2018 (see Table 1). The López -Obrador administration has taken multiple actions to pause key components of market rollout and integration (e.g., renewable energy auctions and investments in transmission to serve isolated, congested areas).
Congestion management	Congestion pricing is structured to minimize congestion costs. The ISO monitors monopoly power abuse in constrained areas.	CENACE has set FTRs for CFE and has information on loads and marginal local prices (MLPs). It also monitors real-time demand and supply.	In the summer of 2018, CENACE established basic service tariffs in reference form only. These end user tariffs need to be finalized and implemented for congestion pricing to be effective.

Parallel path flow to guarantee network security	The ISO ensures that the system allows electricity to access a single network node via multiple routes. The network has the redundancies necessary to manage outages.	Metrics like grid efficiency and reliability are in place and appear to be improving per Mexico's "Market Rules" and "Grid Code". Per SIE, from 2017 to 2018 average transmission interruptions declined from 11.1 to 6.2 minutes and the average number of outages per user dropped from 0.5 to 0.2.	Coverage is at less than 100%. The López-Obrador administration cancelled several planned transmission expansion projects that regulators had prioritized for enhancing and integrating Mexico's electricity network.
Ancillary services	The ISO has reliability services like load following reserves, markets for energy imbalances, voltage control, and black start capability in place.	Five ancillary services appear in Mexico's "Market Rules", and grid operators are collecting data on prices before these markets roll out.	CENACE has not established prices for nor launched an ancillary services market in Mexico. This represents an implementation delay versus Mexico's Energy Reform timeline.
Non-discriminatory, open access	The ISO provides transmission access via a universal, non-discriminatory platform. The ISO is responsible for oversight and operation of the platform.	This is included in Mexico's "Market Rules". CENACE identifies areas where transmission access is critical.	Participant implementation and participation in the supply and final demand was only marginal and incipient at mid-2018. The López Obrador administration placed action in critical areas on hold.
Market monitoring	The ISO monitors geographic sub-markets formed by local congestion. It also seeks to minimize the system cost of market abuse.	Market monitoring is part of CENACE's responsibilities under its charter, and its tariffs are totally socialized (postage stamp). It also engages in expansion planning and oversees contract signing.	CENACE oversees incipient market participants' operations, but there is no market standard in place to check for market abuse.

Sources: Pollitt (2012); SENER (2017 and 2019); CENACE (2015 and 2017), SIE (n.d.) and CRE (2018).

While CENACE is on track to fulfill most of the minimum functions outlined in this table in the medium term, the table shows lack of progress to date in all submarkets, including ancillary services development.

Other areas that will be especially important for CENACE to address in terms of encouraging renewables uptake include improving congestion management and parallel path flow to accommodate for the flexibility that an increasingly renewable-driven grid demands (Mohler and Sowder, 2017, p. 285). As it plans grid expansion and interregional coordination of control areas, CENACE can develop strategies to harness renewable resources in areas with high wind, solar, and/or geothermal generation potential while also considering transmission pinch points across regions that may arise due to high-renewable generation scenarios. Its capacity as a market monitor and tariff designer also positions it well to continue to open the wholesale market to new participants and provide a fair platform for their participation, reducing costs through greater competition in generation and transparency in pricing. CENACE's continued role in serving as the sole provider of transmission services is also a key feature of ensuring nondiscriminatory access to new generators, renewable or otherwise (FERC, 1999, p. 330).

An additional dimension added to this framework is the speed of moving from a centralized governance CENACE model towards a true market with minimal central intervention. Moreover, the Lopez-Obrador administration has been slow to define whether the market will aim to enhance market-driven incentives or opt to rely more on direct government intervention and government-led calls for investors to participate. An example of a more market driven approach would be for CENACE to permit participants to trade in wholesale electricity and shift towards a neutral-passive role in the market clearing processes. Speed and strategy of increased implementation of market functions is critical for success, especially as it pertains to swiftly developing approaches that support renewable uptake and utilization.

Given the rapidly changing nature of Mexico's electricity system and CENACE's identified need for performance assessment and metrics (CENACE, 2017), the application of minimum market functions to CENACE's first, second, and third years is a contribution toward building an updateable assessment framework. As wholesale markets continually develop, market operators and monitors can establish new minimum functions as needed, which can be combined with those outlined above. From the established minimum market functions, market operators can go into further detail to create performance metrics. The following section: a) expands on insights from the minimum functions evaluation, including FERC metrics for ISO evaluation that were developed after 10 years of the ISO/RTOs operation in the U.S., and b) highlights critical aspects of market performance that are relevant to Mexico's current transition toward an increasingly renewable grid, and policy needs.

FERC's ISO Performance Metrics as a Point of Reference for the Mexican Transition

Under the U.S. General Accountability Office's recommendation in 2008, FERC began creating performance measures of U.S. RTOs/ ISOs and collecting voluntary input from non-RTO electric utilities (GAO, 2008). FERC also established performance and reliability/systems operations metrics, which it reviewed and updated in 2014 and further in 2017 (FERC).

As part of the update, FERC identified 27 reliability metrics and three systems operations metrics, which are more quantitative and detailed than the original minimum functions approach from 1999. Fifteen of these metrics are especially relevant to the case of supporting renewable integration through development of ancillary services. The highlighted metrics are the crux of the present analysis and are presented in association with aforementioned minimum functions to illustrate an initial framework, which begins with a broader minimum

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market function and leads to establishing measurable indicators for wholesale success. At present, none of these associated FERC metrics are present in CENACE's self-report and first planning exercise (CENACE, 2017).

As can be noticed in the following Table 3, five fundamental dimensions are presented as "minimum functions" in the wholesale market: a) Ancillary services and their benefit in transitional market with scarce reserves; b) parallel path flow to guarantee network security in a new market with increasing nodes and loads; c) grid expansion projects; d) tariff administration in a disaggregated and layered market with increasing renewable capacity needs; and d) congestion management in the transitional market.

Table 3
FERC Reliability and Systems Operations Metrics by Minimum Function

Minimum Function	Associated Metric
Ancillary Services	Planned reserves versus actual reserves.
	Unserved energy (load shedding), considered a violation. Aim to preserve reliability and protect systems load during certain daily events.[3]
	System lambda.[4]
	Balancing authority minimum compliance of error in frequency at interconnection (Control performance standard 1, or CPS1), in percentage above minimum requirement.
	Percentage variation of planned load and actual load in the day-ahead market for overall load and wind.
	Demand response indicators (i.e., resources dedicated to demand response).[5]
Parallel path flow to guarantee network security	Minimum unscheduled power flows, measured as a standard called CPS 2, not to be below 90% of total flows.
	Unscheduled flows from planned flows, both at interties and parallel flow (loop flow) or contract paths, measured in million MWh and percentage change from 2010 to 2014.
Grid expansion	Number of approved transmission construction projects for reliability purposes.[6]

[3] Note that all U.S. RTOs/ISOs plan and operate transmission, and they are the TO service providers, except for Southwest Power Pool (SPP) in operation and CAISO and Midcontinent ISO (MISO) in transmission operations planning.
[4] System lambda represents the incremental cost of energy derived from the economic dispatch function performed by a balancing authority area's control center. It is the incremental cost of a marginal generating unit, with no system's constraints in losses or congestion, expressed in U.S. dollars per million Btus, then translated to dollars per MWh.
[5] This metric could be enhanced by new resources committed, such as new ancillary services expense, complementarities or substitutability with respect to increased transmission expansion investment, or energy storage projects, new technology integrated, which is some metric of key interest for the present quantitative evaluation of ISO/RTO commitment in the U.S. and also for Mexico's CENACE.
[6] Note: in FERC-922 report, construction permits vary across ISO/RTOs, from above 500 in MISO for years 2013 and 2014, to less than 50 in CAISO and New York ISO.

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Tarff administration	System operations performance metrics, including outage rates, and generating capacity by type of fuel. Percentage renewable capacity and hydro-generation capacity; percentage natural gas and oil-fired capacity. Disaggregated energy costs of the wholesale market (share of energy, capacity, reserves, ancillary services, financial transmission rights, transmission services, transmission loss, transmission congestion, energy imbalance) in dollars billed. Convergence between the day-ahead market and real-time market prices. New entrant net revenues by year (as an indication of signals for increased investment and commitment).
Congestion management	Net revenue as a percentage of total congestion costs (as in CAISO).

Source: FERC, 1999 and FERC, 2010-2017.

As can be observed, the fifteen critical metrics under the five "minimum functions" headers or constructs maintain a smoothly running market along the lines of the planned expansion. They also ensure the necessary ISO/ RTO's governance over a wholesale market with numerous participants and sub-markets.

Beyond its role in direct assessment of ISO/RSO performance as outlined in Table 3, FERC oversees the North American Electric Reliability Corporation (NERC). NERC is a nonprofit organization that ensures the reliability of the North American bulk power system. NERC was established as part of the U.S. Energy Policy Act of 2005, passed in response to increasing electricity restructuring efforts and reliability events such as the Northeast Blackout of 2003 (NERC, 2014). NERC's key focus areas include electric bulk power system reliability, assurance, continued learning, and encouragement of a risk-based approach. Specifically, NERC develops standards for reliability, assesses long-term reliability, and identifies any threats to reliability. NERC's purview includes the continental U.S., Canada, and the northern portion of Baja California in Mexico (NERC, 2017).[7],[8] FERC minimum functions/metrics and CENACE's existing branches of collaboration with NERC are helpful points of reference for CENACE as it continues to develop its wholesale market in parallel with Mexico's increased renewable uptake.

[7] Northern Baja Mexico is part of the Western Electricity Coordinating Council (WECC), which also oversees reliability in reliability in 2 Canadian provinces and 14 U.S. states.
[8] In March 2017, CRE, CENACE, and NERC signed a memorandum of understanding recognizing each organization's role in contributing to reliability and establishing objectives to collaborate to achieve the shared goal of system reliability (NERC, 2017).

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Conclusions

Within the context of Mexico's incipient market, rapidly evolving electricity system and CENACE's observed need for continued assessment structures, this research has sought to provide CENACE and Mexico's electricity sector regulators with additional perspectives for its path forward. The application of FERC's minimum market functions to CENACE's first years is an important first step to build an evolving assessment framework upon which evaluation metrics and internal assessments can be designed. CENACE and other regulators in Mexico's recent past, have used the institutional dynamics in some US ISO's and energy markets, as key referents for enhancing market operations in Mexico, irrespective of the political cycle. Additionally, economic theory can be applied to policy design to clarify viewpoints across presidential administrations in Mexico. This approach could illuminate differences and similarities in market design and energy policy.

CENACE and U.S. RTO/ISOs have much to gain from sharing experiences related to the rapidly evolving, increasingly renewable and responsive electric grids that are revolutionizing the electricity sector across many parts of the world. CENACE has an opportunity to review successes and failures of U.S. RTO/ISOs as its market moves ahead, and U.S. RTO/ISOs benefit from staying connected to CENACE's development to see how the new market responds and adapts to renewable penetration on a large scale. Collaboration between the U.S. and Mexico on how to best harness and regulate increased renewable generation both are seeing across their markets will inevitably yield greater benefits in terms of cost reductions and environmental benefits for both parties than if the nations set out to solve the complex challenges on their own. Further research should focus on policy design with measures of the depth and width of wholesale electricity markets. Depth would mean the use of multi-layered but convergent policy decisions of all sub-markets. Width would imply applying policy measures and plans beyond simple performance measures and extending them to similar, but more mature markets. All improvement measures should apply irrespective of policy design in Mexico's recent energy policy and regulatory changes.

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