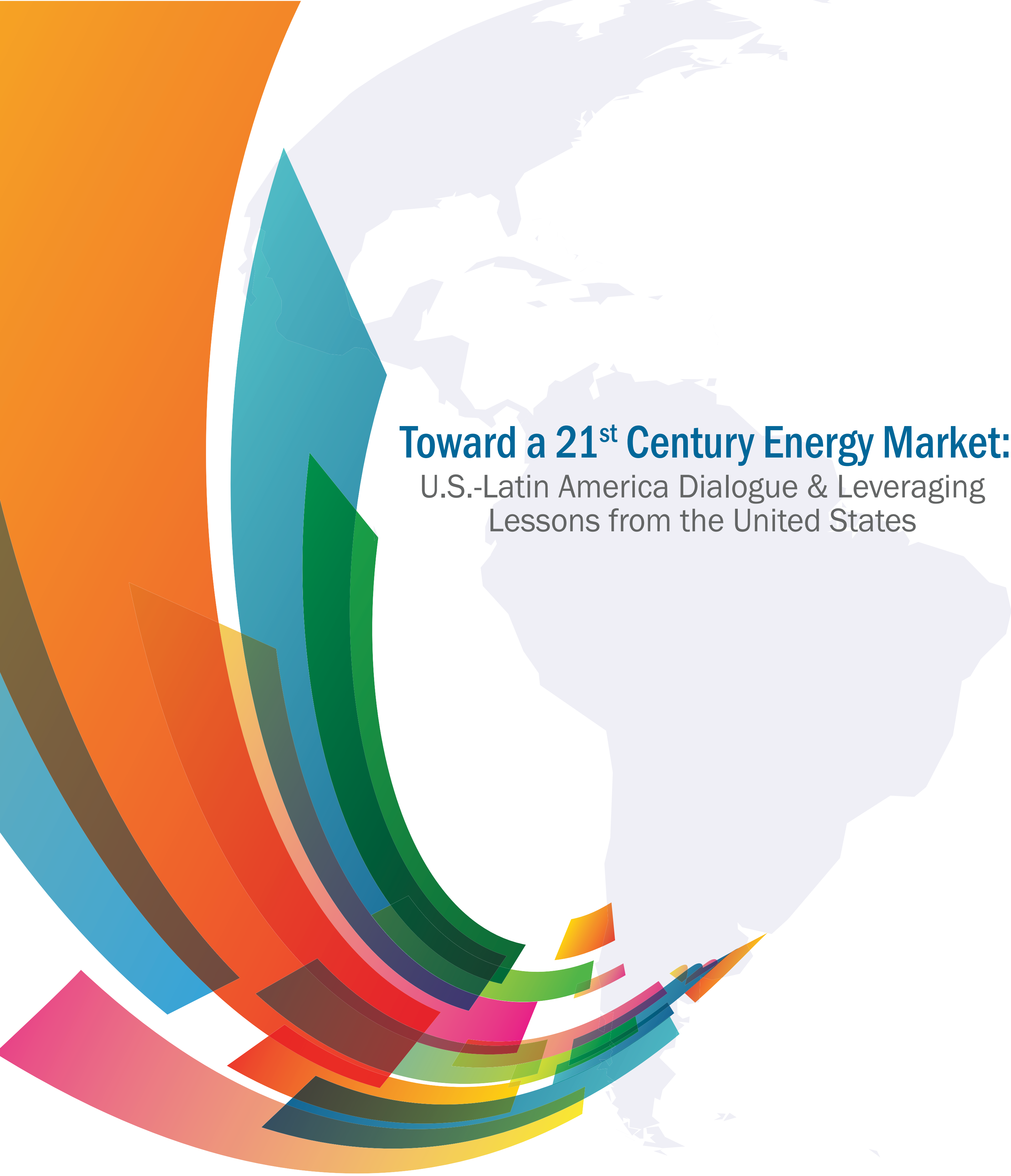

Toward a 21st Century Energy Market:

U.S.-Latin America Dialogue & Leveraging Lessons from the United States

With the Support of:

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Foreword

The Institute of the Americas (IOA) was grateful to have the support of CAF – Development Bank of Latin America and to be able to collaborate on this important research paper and analysis. For several months, and through a number of meetings and discussions, we conceived of a research project that sought to succinctly address the question of: “What can the United States and Latin America do together?”

The mission of the IOA’s Energy & Sustainability program is to foster a deeper understanding of the Western Hemisphere’s most critical energy and sustainability issues. We are confident that this report and analysis meets that objective and will contribute in a positive manner to further informing linkages between the United States and Latin America when it comes to energy, possible areas for collaboration, enhanced partnerships, commercial opportunities, how to overcome hurdles, and the most likely areas for near-term and medium-term cooperation.

Given the rapidly changing developments in the global energy landscape, but particularly in the United States in the last few years, the goal of the research was to foresee a path forward for dialogue and action toward what we have called a 21st Century energy market that is based upon and informed by practical lessons from the United States.

Therefore, our research and analysis sought to understand how best to connect what is occurring in the United States in an effort to build bridges with Latin America with a focus on interconnection and grid reliability, renewable energy, energy efficiency, and shale and unconventional resources.

Throughout our public and private discussions across the region, these issues have been repeatedly underscored as critical themes and will be key focal points of future dialogue and efforts aimed at building a 21st Century energy market.

Our research team led by **Ashley Brown**, Executive Director of the Harvard Electricity Policy Group and his colleague Louisa Lund did a masterful job of unraveling the intricacies of the United States electric sector and unconventional resource developments. They are to be commended for translating such a complex topic to understandable language and allowing for a better understanding of what the major changes underway in the United States signify. Through this report these lessons will be leveraged to shape and inform the hemispheric energy policy debate and dialogue.

We greatly appreciate all of the support from CAF for this undertaking, and particularly Mauricio Garron and his team who worked diligently throughout the entire research process and in finalizing the white paper.

JEREMY M. MARTIN
VICE PRESIDENT, ENERGY & SUSTAINABILITY
INSTITUTE OF THE AMERICAS

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Acknowledgements

The authors would like to thank the Institute of the Americas/CAF for its support in writing this paper. In particular, we would like to thank Jeremy Martin, Vice President, Energy & Sustainability, Institute of the Americas and Mauricio Garron and his colleagues at CAF for their input. All errors and omissions are our own.

Introduction

The purpose of this paper is to review some of the key issues and trends related to energy in the United States, with particular attention to the electricity sector and to the development of shale oil and gas, in order to set the basis for a meaningful dialogue between the U.S. and Latin America on emerging energy issues. The U.S. experience in the electricity sector and in the development of shale oil and gas offers many rich examples of how the complex relationships between markets, technology, regulation, and public policy can play out, and also of how markets are being constrained, challenged, and forced to innovate by new technology developments and public policy pronouncements.

In tracing these themes of markets, technology, and regulation, we examine the fundamentals of the U.S. electric grid and the emergence of a standard open access market design, along with the limits of the U.S. markets, including the rather arbitrary division of control areas and the creation of artificial "seams" interrupting electricity dispatch. We then discuss several factors with the potential to contribute to a virtuous cycle, strengthened by markets and strengthening them in turn—innovation, access to information, as well as smart grid and smart meter technology.

Turning to the impact of policy, we examine how policy objectives to promote renewable energy and energy efficiency are being incorporated into the U.S. electricity system, contrasting policies that cause market distortions with other approaches that are more in harmony with markets, and examining how third parties and consumer education might play a role in integrating renewable energy and energy efficiency measures into the electricity sector.

Finally, we examine the development of shale oil and gas, which has had a tremendous impact on the U.S. energy sector, focusing on several special circumstances—concession systems, market structure and design, and the financial ecosystem, which may have played a role. In conclusion, we ask what, if anything, from the U.S. experience may be generalizable, or may suggest new opportunities for Latin American countries, an analysis which is intended as a starting point for future discussions.

Interconnection, the Decentralized U.S. Electric Grid, and Reliability

Regional Transmission Organizations (RTOs) and Markets

Beginning in the 1990's, the United States, like many other nations in the Americas and elsewhere, adopted public policies that encouraged utilities to move towards open access and competition in the provision of electricity. Such policies also encouraged new entrants, such as independent power producers, to enter the market. The effort to "restructure" what had for a long time been largely, although not exclusively, a privately-owned and -operated system of vertically-integrated regional utilities, regulated primarily by state governments, has had to grapple with a fundamental challenge.[1] How do you allow open access to the transmission system while maintaining high levels of reliability and efficiency? Somebody must be in charge, telling power plants when they can and cannot put power on the system, to protect the stability of the system, but doing so in an economically efficient manner. In a vertically-integrated utility, the problem is easily solved. A central system operator dispatches plants, using the most efficient first, subject to the physical constraints of the transmission system and to certain standards intended to preserve the robustness of the system in case of failure of a plant or a line (*i.e.*, security-constrained economic dispatch). The puzzle is, how do you reconcile the need for total central control of the transmission system with free wholesale market competition, when all

[1] A helpful overview of the history of the U.S. electric system and the introduction of completion can be found in Tuttle, David P., Gülen, Gürcan, Hebner, Robert, King, Carey W., Spence, David B., Andrade, Juan, Wible, Jason A., Baldwick, Ross, Duncan, Roger, "The History and Evolution of the U.S. Electricity Industry," White Paper UTEI/2016-05-2, 2016, available at http://energy.utexas.edu/ the-full-cost-of-electricity-fce/.

plants are supposed to have access to the transmission system to sell their power?

A solution to the problem can be found in a version of security-constrained economic dispatch that is open to bids from all who would like to provide power to the system. All would-be participants indicate their interest in providing power, at whatever minimum price they choose. The dispatcher then uses this information to determine the most efficient secure dispatch and tells plants to operate accordingly, paying all plants the price of the highest-bidding plant dispatched Anyone (meeting certain minimum requirements) can participate, so the system is "open access" and competitive, even though it is also centrally managed.

The strong functioning of such a system requires an impartial dispatcher—one without any incentive to skew the dispatch results to favor any one generator or set of generators. In the United States, with regulatory oversight provided by the Federal Energy Regulatory Commission,[2] this role has been filled by the development of a system of independent, non-profit Regional Transmission Organizations (RTOs, also sometimes referred to as Independent System Operators, or ISOs), each a not-for-profit corporation, responsible for running the bidding system and managing power plant dispatch within its own region.

While the idea of regional transmission organizations has not been universally adopted in the United States, currently seven U.S. RTOs manage power serving approximately 60% of United States load.[3] The map of RTOs in the United States and Canada looks like this:

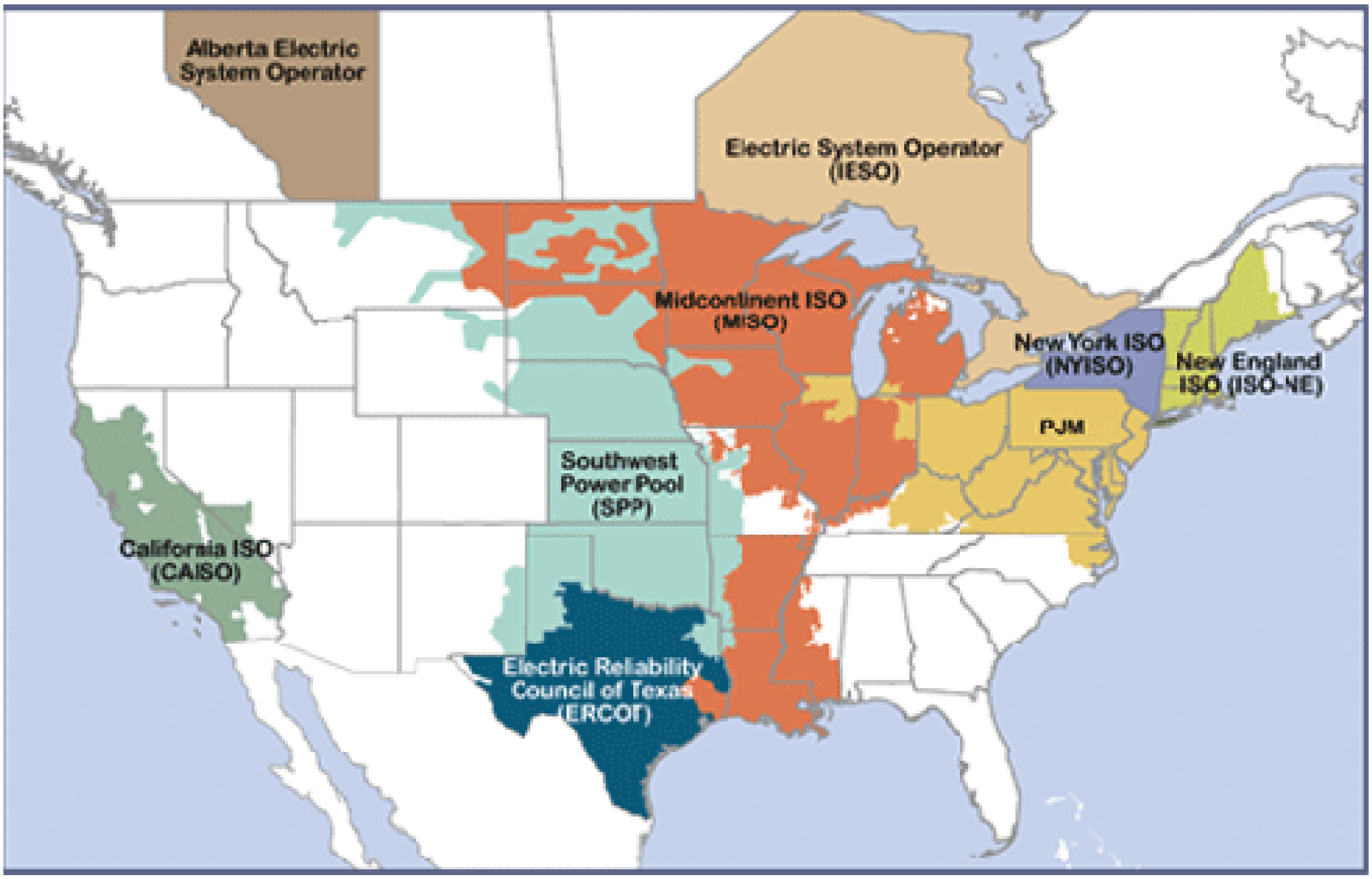

Figure 1: Map of RTOs/ISOs. Source: FERC, https://www.ferc.gov/industries/electric/indus-act/rto.asp

The following sections briefly discuss how markets have evolved in the U.S. RTOs, including the use of locational pricing for congestion management, "seams" issues and the emerging model of California's Energy Imbalance Market, innovation and the barriers to innovation, how information is made accessible, and the

[2] See FERC Orders 888, 889, and 2000.

[3] Source: EIA. Load service estimate is for 2009. https://www.ferc.gov/industries/electric/indus-act/rto.asp

growing role of "smart grids" and "smart meters" within this structure.

Market Design, Congestion Management and Locational Prices

After an initial period of experimentation (one which included such notable failures as the California electricity crisis of the early 2000s), what has emerged is convergence around an increasingly standard, uniform (*i.e.*, where RTOs are in place) model of a working wholesale electricity market: "bid-based, security-constrained economic dispatch with locational pricing," with financial transmission rights available to manage transmission cost risks.[4]

"Locational pricing," or "locational marginal pricing," (LMP), which has been adopted by all U.S. RTOs, is an important element of market design in the United States. Locational pricing serves two very basic purposes. The first is that it dramatically reduces the need for the system operator to administratively re-dispatch the system. That is because the full costs of congestion and grid dynamics are reflected in the costs of delivering energy across thousands of specific nodes on the system. That price varies in real time and at multiple real locations, depending on what is occurring on the grid. The system operator runs generation bids and demand projections through an optimizing algorithm that calculates the marginal impact of the last unit of demand on the costs for the whole system and prices electricity at each node in the system independently based on this calculation. If demand for electricity at a specific node is hard to meet due to congestion in transmission, the system operator might be constrained to dispatch a more expensive but better-located plant in order to meet demand at a given node.

This raises electricity costs for the whole system—and the price paid at the problem node will reflect the full impact of demand at that node on the cost of electricity. (The difference between the price at a congested node and the price at an unconstrained node is referred to as "congestion rent"). For this reason, electricity prices can vary dramatically among nodes on the same network, depending on congestion. Those varying price signals indicate to generators when they may or may not want to bid and at what price. These price variations also send signals to new generating plants as to where they would be able to optimally, in terms of grid costs, site their next plant.[5] The second fundamental purpose of locational pricing is to turn administrative decisions regarding dispatch and re-dispatch into economic decisions each market participant can make for itself. The result of that shift is to make the market more competitive and less subject to non-economic intervention.

While there were initial complaints that LMP, because it is subject to after-the-fact price adjustments, injected a level of uncertainty into the market that participants could not manage, that criticism has gradually dissipated for three basic reasons. The first reason is that, over time, the pricing patterns became transparent enough for market participants to be able to develop and use models that permitted more sophisticated decisions regarding buying and selling energy. The second reason that market participants became more comfortable with LMP was the emergence of Financial Transmission Rights (FTRs), which enabled market players to hedge against volatility in LMP. With FTRs, it is possible to buy the right to the "congestion rents" between nodes, and a power customer or supplier concerned about exposure to congestion pricing can protect themselves by purchasing such rights. In combination, locational pricing and financial transmission rights provide a financial incentive to generators and load to choose locations for new facilities so as to minimize grid congestion, whenever possible.[6] The third reason is that

[4] This account of experimentation and convergence is based on the ideas of William Hogan. See Hogan, William W. "Electricity Market Restructuring: Reforms of Reforms*." *Journal of Regulatory Economics; Norwell* 21, no. 1 (January 2002): 103. These ideas are also discussed by Hogan in numerous presentations. One of the most thorough of his presentations on this topic is "Successful Market Design ("SMD") and Failure Diagnosis: Blackouts and Lampposts in Regulating Electricity Markets" (October 9, 2003). Presentation by William Hogan, Regulatory Policy Program Seminar, Center for Business and Government. (40 pages). https://www.hks.harvard.edu/fs/whogan/Hogan_RPP_100903.pdf For more on the California case, see Borenstein, S. (2002). "The trouble with electricity markets: understanding California's restructuring disaster." Journal of Economic Perspectives. Retrieved from http://www.jstor.org/stable/2696582.

[5] Similarly, price signals can incentivize demand to locate in areas where congestion is low.

[6] This is a very brief discussion of a complex problem. For further discussion, see Bohn, R. E., Caramanis, M. C., & Schweppe, F. C. (1984). "Optimal pricing in electrical networks over space and time." *The Rand Journal of Economics*. Retrieved from

LMP provided a market basis for relieving congestion and many security constraints, a mechanism that allowed the system users to make rational economic decisions, as opposed to subjecting themselves to the vicissitudes of administrative re-dispatch.

"Seams" issues between RTOs and the growing Western Interconnect

The patchwork system of system operators (ISOs/RTOs) in the U.S. (as well as large parts of Canada, which are interconnected to the United States) does not map particularly well to the physical structure of the U.S. grid, which is essentially three separate "interconnects," the Western Interconnect, the Eastern Interconnect, and the Electric Reliability Council of Texas. Within each of these large grids, power flows freely; however, only the Texas grid is governed by a single system operator. Elsewhere, the flow of electricity between regions operated by separate system operators is managed outside of the wholesale market—a system that creates inefficiencies known as "seams issues" that must be administratively managed.

Electricity trading across seams and between RTOs does occur, but with considerably less efficiency than trading within RTO wholesale markets. Since 2014, California has been spearheading an effort to better coordinate inter-state energy trading in the West, creating an "Energy Imbalance Market" that coordinates dispatch among participating western RTOs, aimed at reducing costs, increasing reliability, and better integrating California's renewable electricity. The California ISO serves as the market operator, with current participants including PacifiCorp, NV Energy, and Arizona Public Service. Recent reports even suggest that the Mexican electric system operator's Baja California Norte division may consider participating.[7]

Innovation

One of the key motivations behind the initial push to restructure U.S. electricity markets was to allow competition and thereby provide incentives—and remove impediments–for power market participants to innovate. In a vertically-integrated, regulated utility, the disincentives to innovation are well known. Utility regulators set prices to reward prudent investment with a cap on allowed profits. There is no provision for windfall profits to reward an especially bold and successful experiment—but there is a distinct possibility that regulators might refuse to allow rate recovery of an investment they deem imprudent. In short, utilities are incented to be risk avoiders rather than risk takers.

The introduction of open-access wholesale markets addresses part of this problem. Investors who wish to build new kinds of generation plants are free to do so and to offer the power for sale in the "bid-based" market administered by the RTOs. Plants which can produce power more economically than other plants will be rewarded with additional profits, as they receive the price of the highest-bidding plant dispatched. Alternatively, they can earn money by entering into direct bilateral contracts to sell capacity, energy, and ancillary services, and to engage in hedge transactions that enable effective risk management.

Irrespective of the preceding analysis, finding ways to encourage innovation in other, less competitive sectors of the electricity industry remains a challenge. The regulatory model still applies, for the most part, to distribution utilities, who take responsibility for procuring energy to meet the demand of their customers[8], distributing it to customers, and metering and billing consumption.

http://www.jstor.org/stable/2555444; Hogan, W. W. (1995). "Coordination for competition in an electricity market. Response to an Inquiry Concerning Alternative Power Pooling Institutions Under the Federal Power Act." Retrieved from http://www.hks.harvard.edu/fs/whogan/ferc0395.pdf; International Energy Agency. (2007). *Tackling Investment Challenges in Power Generation in IEA Countries: Energy Market Experience*. *Energy*. Paris. Retrieved from http://www.iea.org/publications/freepublications/publication/tackling_investment.pdf; Hogan, W. W. (1992). "Contract networks for electric power transmission." *Journal of Regulatory Economics*, *4*(3), 211–242. Retrieved from https://www.hks.harvard.edu/fs/whogan/acnetref.pdf and Bushnell, J. B., & Stoft, S. E. (1996). "Electric grid investment under a contract network regime." *Journal of Regulatory Economics*, 10(1), 61–79. Article behind paywall. Abstract at http://link.springer.com/article/10.1007/BF00133358.

[7] "Mexico's Grid Operator May Join EIM," *The California Oil and Gas Report.* Posted October 14, 2016. http://www.caloilgas.com/cenace-to-join-eim/.

[8] The role of distribution companies may vary from state to state in the U.S. In all states a distribution company does own and operate the low voltage distribution system. In some states it is the sole energy provider as well. In states with competitive retail supply, the distribution company may

be the default provider for those customers who do not choose an alternative supplier.

Although several jurisdictions allow greater or lesser retail competition (customers select their own electricity providers, and distribution utilities' function is limited to delivering, metering, and billing for energy), even this leaves important areas as regulated monopolies. With the development of ever more distributed energy resources, smart meters, and demand response capabilities, an important question to ask is whether the current regulatory model is adequate to support and reward innovation in this area. It may be appropriate to re-examine the functions typically assigned to the distribution utility, and ask which of them might be better performed by a third-party entity on a competitive basis. Clearly, the construction and maintenance of the distribution network itself may need to remain a local monopoly; however, there is no reason that services related to metering, billing, and energy efficiency could not be provided competitively, opening greater space for innovation in these areas.[9] The U.S. experience in these matters would be useful to explore in a dialogue with Latin Americans who have had their own varied experiences with the interplay between sector reform and innovation. While there are certainly technological innovations that merit discussion, it might be more useful, at least initially, to discuss the barriers to more innovation and the incentives that might promote innovation. The technology that may ultimately get deployed is in many ways dependent on how barriers are dealt with and what incentives are put in place.

[9] These ideas are discussed further in Brown, Ashley, Steven Levitsky, and Raya Salter. "Smart Grid and Competition: A Policy Paper." Prepared for the Galvin Initiative, July 28, 2011. In California and New York, regulators are pursuing comprehensive efforts to re-organize the distribution of electricity in ways that encourage new (and especially lower-carbon) technologies. For current thinking in California, see DeMartini, Paul, "More Than Smart: A Framework to Make this Distribution Grid More Open, Efficient and Resilient." Greentech Leadership Group. For more on New York's "Reforming the Energy Vision" initiative, see the New York State DPS "Reforming the Energy Vision" page at http://www3.dps.ny.gov/W/PSCWeb.nsf/All/CC4F2EFA3A23551585257DEA007DCFE2?OpenDocument and especially the April 24, 2014 staff report on this topic: http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B5A9BDBBD-1EB7-43BE-B751-0C1DAB53F2AA%7D.

Access to Essential Facility Information

One necessary precondition for competition that has not yet been discussed is access to information. For an entrepreneur wishing to develop new generation, for example, it is important to understand the availability of transmission, where and when congestion is likely, what other generation resources are serving the system, and what prices are being seen, in order to decide whether and where an investment is a good idea.

Recognizing this need, as part of its series of orders establishing the conditions for open-access wholesale electricity markets, FERC issued Order 889 in 1996, requiring the establishment of an "Open-Access Same-Time Information System" ("OASIS") that requires that: each public utility (or its agent) that owns, controls, or operates facilities used for the transmission of electric energy in interstate commerce will be required to create or participate in an OASIS that will provide open access transmission customers and potential open access transmission customers with information, provided by electronic means, about available transmission capacity, prices, and other information that will enable them to obtain open access non-discriminatory transmission service.[10]

It is worth noting that the transparency provided by OASIS is required throughout the country, even in regions without RTOs. Further transparency is provided by the institution of independent "market monitors," required by FERC to provide regular reporting and assessment of whether markets are functioning well. These monitors serve two essential functions. The first is that they scrutinize market functioning to make sure that there are no imperfections that dilute the efficiency and competitiveness of the marketplace. The second function is to observe the behavior of various players in the market to make certain that no one is engaging in anti-competitive behavior or violating the rules. While the monitors lack any

[10] FERC Order No. 889. Full text at: https://www.ferc.gov/legal/maj-ord-reg/land-docs/rm95-9-00k.txt.

to meet demand, rather than investing in new infrastructure, and one which is well adapted to handle intermittent energy resources, such as solar or wind power.[10]

enforcement powers, they issue regular reports on their observations and findings and can make public any systemic problems or misbehavior they observe, including making referrals to regulatory authorities for enforcement actions or corrections of market imperfections. The use of market monitors and transparency of information, in general, would be a good discussion point for a dialogue between U.S. and Latin American electricity experts.

At the distribution levels, issues of transparency have not necessarily been resolved. There is an ongoing debate, for example, about who owns or should have access to information about customer electricity consumption. Greater access to such information might be helpful to allowing third-party competition to supply, for example, efficiency services—but open access to customer information raises concerns about privacy. Some states, notably New York and California, are exploring policies that would make low-voltage grids operate similarly to the RTOs at the high-voltage levels—utilizing tools such as locational pricing, and perhaps a distribution system operator. The objective is to optimize the use of distributed energy resources, such as rooftop solar, micro-generation, demand side management, energy efficiency, and demand response. These developments would make excellent discussion points for a dialogue between the U.S. and Latin America.

Smart Grids/Smart Meters

The fundamental institutions of wholesale markets in the United States—ISOs, bid-based, security-constrained dispatch, locational pricing, and FTRs—have been developed even as the technological possibilities of grids and of metering have been changing. A question that can be asked is whether these institutions appropriately consider the potential of newer technologies, often referred to collectively as "smart grids."

In the comprehensive 2011 MIT *Future of the Electric Grid* study, the researchers note that the usefulness of the term "smart grid" may be limited by the fact that it seems to be used to mean many different things. For this reason, they largely avoid using the term; however, the MIT researchers suggest that "smart grid" is perhaps best thought of as referring to "the expanded use of new communications, sensing, and control systems throughout all levels of the electric grid."[11] Specific technologies that might be relevant, the MIT researchers suggest, include devices such as, for instance, phasor measurement units, which provide more precise information about what is happening on the grid, allowing system operators to maximize grid utilization, with less of a margin of error required. However, none of the technologies mentioned seem to change the fundamental need for a system operator to manage power on the grid.

Taken in a more expansive sense, a "smart grid" could be thought of as a grid in which optimal decisions are made about when to use technology, when to build more transmission or generation, and when to use distributed energy resources or energy efficiency measures

At the distribution level, the idea of a "smart grid" is closely tied in to the technology of "smart meters," or, more generally, "advanced metering infrastructure." "Smart meters" can track household level electricity use in detail (at least hourly) and provide the data remotely to the utility. As of 2015, approximately 65 million smart meters were installed in the U.S., according to EIA data—a significant increase from 7 million in 2007, and with projections of 90 million by 2020.[12]

In theory, the installation of smart meters could permit dramatic increases in the efficiency of the distribution system, as well as enable major gains in the efficient use of energy. A clear efficiency, which has mostly been realized, is eliminating the need for human meter readers to physically read meters every month in order to bill customers. Other benefits would relate to more sophisticated billing options that become available when granular data about customer usage is available—peak pricing, for instance, to charge customers more for electricity use at times when demand—and wholesale electricity prices–are highest. The 2011 MIT *Future of the Electric Grid* study reviewed utility projections of cost

[11] MIT, *The Future of the Electric Grid*, p. 20. Available online at: http://web.mit.edu/mitei/research/studies/the-electric-grid-2011.shtml.

[12] 2015 data from EIA. Source: EIA, http://www.eia.gov/tools/faqs/faq.cfm?id=108&t=3. 2007 data and 2020 projection from Adam Cooper, Institute for Electric Innovation, Electric Company Smart Meter Deployments: Foundation for A Smart Grid (October 2016), Figure 1. (http://www.edisonfoundation.net/iei/publications/Documents/Final Electric Company Smart Meter Deployments- Foundation for A Smart Energy Grid.pdf)

savings associated with smart meters and found that, while operational savings might cover the entire cost of meter installation in some cases, in many cases, utilities counted on increased efficiencies made possible by smart meters in conjunction with demand response and other efficiency programs to make smart meters cost effective.[13] Realizing these efficiencies, however, requires smart pricing, not just smart meters.

Additional barriers to smart meter deployment in the United States have come in part from customer concerns about privacy and unsubstantiated claims about potential health impacts of exposure to electromagnetic fields associated with smart meters. A solution adopted by some utilities and regulatory agencies has been to allow customers to "opt out" of smart meters, often requiring them to pay a fee to cover the additional meter reading and other operational costs associated with continued use of an old-fashioned meter. The issues regarding the policies governing the deployment of smart meters would make for a very useful dialogue. That discussion should certainly look at the costs and benefits (on both the utility and customer's sides of the meter) of smart meter deployment.

Renewable Energy

Given current knowledge about carbon emissions and climate change, one of the key issues in U.S. electricity markets today is the prospect for developing and integrating more renewable energy—a concern that is impacting the management of the transmission and distribution networks and is driving increasing interest in storage technologies and in improving incentives for renewable energy.

Promoting and integrating large-scale renewable energy generation

In the United States, a combination of federal and state policies promotes the development of grid-scale renewable energy projects (primarily wind and solar). Federal production tax credits support wind energy, and investment tax credits support solar power development. Further support varies considerably on a state-by-state basis. As of February 2017, 29 states in the United States have some form of mandated Renewable Portfolio Standard, and an additional eight states have recommended Renewable Portfolio Goals. Targets vary in aggressiveness—the most ambitious states, California and New York, aim for 50% renewables by 2030.[14] In several parts of the country, additional measures are being taken in the form of state or regional cap and trade systems—including the Regional Greenhouse Gas Initiative (RGGI) in the Northeast, and California's cap-and-trade program. Such policies (in conjunction with decreasing system costs) are already having major impacts. Grid-scale electricity supplied by solar and wind more than tripled, nationally, between 2009 and 2016.[15]

In several cases, however, renewables support policies have impacts that pose significant challenges for system operators. Under the terms of the Federal Production Tax Credit for wind facilities, wind generators receive the credit if and only if they produce electricity. For this reason, wind plants have a financial incentive to put electricity on the grid even when prices are zero or negative—with the result that negative prices are becoming increasingly common in several parts of the country, particularly in the mid-Atlantic states, California, and Texas.[16] The impacts of this can be complex and ambiguous, even from the perspective of reducing carbon emissions. An environment with frequent negative pricing can be difficult for more traditional baseload power plants, including nuclear plants, and is one reason the nuclear industry says it is having a hard time keeping nuclear plants economically in operation—which could lead to increased carbon emissions in the system overall.

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[13] MIT *Future of the Electric Grid*, Table 6.1: http://energy.mit.edu/wp-content/uploads/2011/12/MITEI-The-Future-of-the-Electric-Grid.pdf.

[14] Source: DSIRE, operated by the N.C. Clean Energy Technology Center at N.C. State University: http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2017/02/Renewable-Portfolio-Standards_Feb2017.pdf.

[15] Calculated based on EIA data. Source: *EIA Short-Term Energy Outlook*, February 7, 2017 release. http://www.eia.gov/forecasts/steo/xls/Fig26.xlsx [note this is a file download, not a direct hyperlink. To download file, copy and paste address into internet address bar].

[16] Naureen Malik and Harry Weber, "One Thing California, Texas Have in Common Is Negative Power." April 5, 2016, Bloomberg.com: (https://www.bloomberg.com/news/articles/2016-04-05/one-thing-california-texas-have-in-common-is-negative-power).

In a state like California, an aggressive renewable portfolio standard, including significant growth in solar power production, poses additional challenges having to do with how solar production begins in the morning, peaks in mid-day, and vanishes near sundown. A 2013 analysis by the California ISO coined the idea of a "duck curve" as illustrating the kind of growing challenge this may present for system operators.

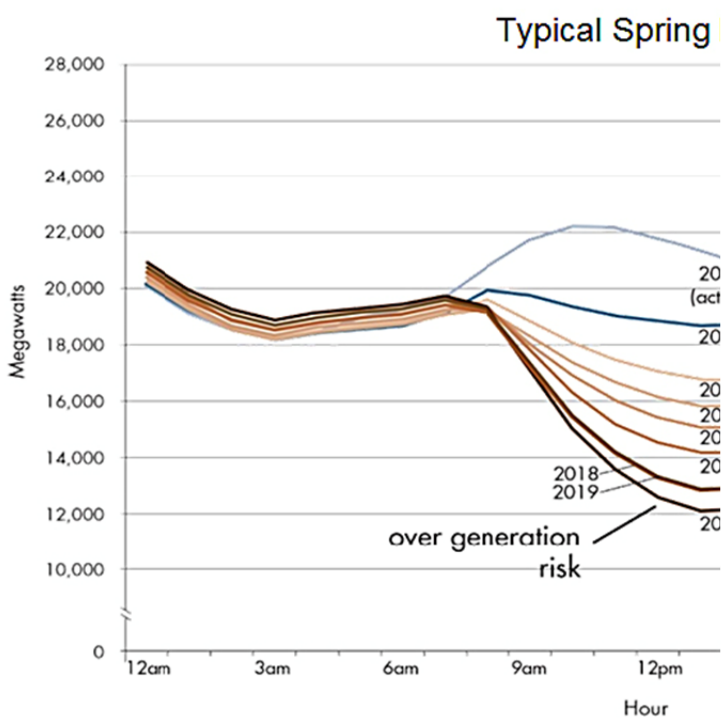

Figure 12: California ISO, Net Load on a Typical Spring Day[17]

Briefly stated, the "duck curve" refers to the phenomenon by which solar generates large amounts of power in the middle of the day, but as solar production declines throughout the afternoon, the corresponding increase in demand must be met by other generation supplied or procured by the utility—a pattern that creates a dip in the "net load" (defined by CAISO as "the difference between forecasted load and expected electricity production from variable generation resources") when increasing solar production is projected out over a number of years, a graph resembling a duck, such as the one shown in Figure 1, with the "belly" of the duck showing a projection of very low levels of mid-day demand for conventional resources as more intermittent renewables (specifically, solar) come on-line. The "duck curve" phenomenon is illustrated in the chart above drawn from the California ISO, in which the belly of the duck shows the increasingly steep drop off and ramp up of net load (that is, load that must be served by conventional resources) that is occurring and expected to increase with greater adoption of solar generation.

Policies Regarding Distributed Renewable Generation

In addition to support for grid-scale renewable development, state and federal policies provide significant support for distribution-level renewable resources, primarily rooftop solar installations. Tax credits from the federal government reward investment in such systems, and many states supplement federal incentives with their own package of incentives, which may include the ability to sell Solar Renewable Energy Credits (SRECs) and access to preferential "net metering" rates. Recently, efforts are being made to compensate rooftop solar owners based on analysis of the "value of solar" energy provided to the grid.

The distortions introduced into the rate system by net metering and "value" compensation, while having some political appeal, are deeply problematic.[18] Net metering, which compensates rooftop solar owners for their production at the full retail electric rate, significantly overpays these customers for the energy they provide to the system, with the result that customers that do not own solar power (on average, probably a less affluent group) subsidize those that do. Those that defend large payments for rooftop solar energy often turn to an argument that the full "value" of what is supplied includes distribution and supply cost savings worth far more than the cost of energy itself. Upon close inspection, however, these savings turn out to be predominantly unquantifiable, hypothetical, and often completely imaginary.

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[17] Chart is from California ISO "Fast Facts: What the Duck Curve Tells Us About Managing a Green Grid." 2016. https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

[18] Brown, Ashley, Jillian Bunyan. "*Valuation of Distributed Solar: A Qualitative View*." *The Electricity Journal*. 27.10 (2014): 27-48 (article behind paywall at http://www.sciencedirect.com/science/article/pii/S1040619014002589); and Brown, Ashley, "The value of solar writ large: A modest proposal for applying 'value of solar' analysis and principles to the entire electricity market." *The Electricity Journal*. 29.9 (November 2016): 27-30 (article behind paywall).

Net energy metering was adopted by utilities at a time when rooftop solar was prohibitively expensive, with the idea of fostering an infant technology. Now that costs of solar have come down considerably, adoption has grown considerably, and the costs of net energy metering programs are growing correspondingly, many utilities are reexamining this rate. In state after state, pitched battles are erupting as entrenched solar interests resist utility efforts to reform net energy metering rates.[19] These developments are also linked in many ways to the issue discussed above regarding the operations of distribution systems. These types of issues have already arisen in Brazil and perhaps other parts of Latin America and seem likely to arise elsewhere, making this subject an attractive one on which to base dialogue.

Managing Intermittent Energy Resources: Hopes for Transmission and Storage

Faced with difficulties such as negative wind prices and the duck curve, policymakers are looking to improved transmission and storage to help maximize the benefits of renewable energy.

Transmission is especially important for wind power—the areas with the best wind resources are not generally densely populated areas with significant load. (This is true not only in the United States, but also in Latin America). Transmission, especially interstate transmission, can be very hard to build, as multiple stakeholders must agree, and those who are seeing transmission built to take cheap energy out of their state, especially, may not see much benefit in supporting this kind of project. There is a "chicken and egg" problem associated with transmission and wind generation. Do we build the transmission in hopes the wind will follow, or do we do the reverse, developing the wind and then the transmission? The reason this is a problem is because there are diverse models for attracting capital for transmission and generation (e.g. derived from different sources for the generation than it is for the grid, generation commonly has to construct transmission also, and a variety of build and purchase arrangements are used) . Even if there were a common investor for both sectors, there is a question regarding the ability to attract sufficient capital. There is also the question of the degree to which the risks associated with investment are socialized or remain concentrated in the investors.

One way to manage this issue is targeted transmission expansion to support the integration of wind power. An example can be found in the Texas CREZ (Competitive Renewable Energy Zones) program. The program was motivated by the idea that the best wind resources in Texas were far from load, and would need additional transmission in order to be fully developed. The Texas Public Utilities Commission studied the wind resource in different parts of Texas, and designated the most promising areas as Competitive Renewable Energy Zones. Then the system operator identified transmission projects that would allow new generation in these areas to reach load and selected transmission service providers for these projects. It should be noted that although the planning was focused on the needs of wind power, the lines themselves are open access. The result was more than three thousand miles of new transmission lines.[20] A recent report from the ERCOT Independent Market Monitor found that the occurrence of negative wholesale electricity prices in ERCOT has dropped to insignificant levels since the completion of the CREZ projects.[21]

No amount of transmission, however, can fully address the problems of variable energy resources, to the extent that they are tied to limited hours of availability. Texas wind power, for instance, produces plentiful electricity during the small hours of the morning, when it is not needed—a problem transmission alone cannot resolve. Similarly, load

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[19] Proposed changes are often controversial. In Maine, a law that would have replaced RNM with an innovative system combining bidding, procurement targets, and long-term contracts was recently vetoed by Governor LePage, and the Commission has now adopted a plan to phase out net metering over time. Hawaii recently ended its RNM program. In Nevada, RNM reform has resulted in a boycott of the state by some major solar installers, and now may face repeal by the current Commission. Arizona's Commission has also issued an order ending RNM. Vermont has reduced the amount of its RNM subsidy. Other states which are at various stages of review and revision include not only Kansas, but also Utah, Massachusetts, Ohio, New Hampshire, Louisiana, and recently Colorado.

[20] Warren Lasher, Director of System Planning, ERCOT, "The Competitive Renewable Energy Zones Process." Presentation, August 11, 2014. (https://energy.gov/sites/prod/files/2014/08/f18/c_lasher_qer_santafe_presentation.pdf)

[21] *RTO Insider, "*ERCOT Board of Directors Briefs: IMM Says Negative Prices Now 'the Exception.'" April 25, 2016 (https://www.rtoinsider.com/ercot-board-of-directors-briefs-25388/)

shape challenges like the California "duck curve" are not fully resolvable through transmission expansion. With this in mind, many policymakers are looking hopefully towards the potential for storage technologies to transform renewable energy from a variable resource into one which can be stored and dispatched at will.

For grid-scale wind and solar installations, this would mean large-scale storage. In 2013, California adopted a utility-scale energy storage procurement target for utilities totaling 1,325 megawatts by 2020 (with installation required by 2024).[22] Utility-scale storage mandates have been adopted or are under consideration in several other states (Washington, Oregon, Nevada, New York, and Massachusetts, as of January 2017).[23]

Similar interest is being shown in behind-the-meter storage, which could, for example, store excess power from rooftop solar systems for the homeowner's use in the evening hours and could also provide some protection against power outages due to weather or other local causes. California's storage mandate includes a requirement for a minimum amount of behind-the-meter storage. Several other states are looking at ways to encourage behind-the-meter storage as part of their distributed energy programs.[24] Ironically, however, existing net energy metering programs to encourage rooftop solar installations may be having the effect of depressing potential interest in behind-the-meter storage—under a typical net metering program, the utility itself acts as the financial equivalent of a free battery for rooftop solar owners, providing no financial incentive for investment in storage technologies. With the movement to change net energy metering programs to include more cost-reflective components, such as demand charges, however, incentives for homeowners to consider investing in behind-the-meter storage technologies may increase.

While lithium-ion batteries currently dominate the energy battery market (not considering pumped hydro in this category),[25] new technologies such as "flow" batteries, are under development. Whatever technologies are developed, the major obstacle to using storage to smooth variable energy resources is likely to be finding a way to make storage use economic. In theory, storage can provide value both in the form of ancillary services, and by arbitraging prices—storing energy at times of low or negative prices, and providing it to the grid at times of higher prices. There may be challenges, however, to providing this service at a large scale—the more facilities provide price arbitrage, the smoother prices will be, and the less money can be made in this way. Furthermore, natural gas facilities, with their relative flexibility in terms of power output, can be thought of as competitors for storage in providing flexibility to the grid—very strong competitors, given the recent low price of natural gas.[26]

Recently, the Federal Energy Regulatory Commission issued a Notice of Proposed Rulemaking related to energy storage. The proposed rule would call on system operators to find ways to better allow storage resources to participate

[22] For details, see California Public Utilities Commission site: http://www.cpuc.ca.gov/General.aspx?id=3462.

[23] Simon, Brett and Daniel Finn-Foley, GTM Energy Research. "State of the U.S. Energy Storage Industry: 2016 Year-in- Review." Presentation, prepared for Clean Energy States Alliance, January 2017. (http://www.cesa.org/assets/2017-Files/ESTAP-webinar-slides-1.27.2017.pdf)

[24] Simon, Brett and Daniel Finn-Foley, GTM Energy Research. "State of the U.S. Energy Storage Industry: 2016 Year-in- Review." Presentation, prepared for Clean Energy States Alliance, January 2017. (http://www.cesa.org/assets/2017-Files/ESTAP-webinar-slides-1.27.2017.pdf)

[25] Simon, Brett and Daniel Finn-Foley, GTM Energy Research. "State of the U.S. Energy Storage Industry: 2016 Year-in- Review." Presentation, prepared for Clean Energy States Alliance, January 2017. (http://www.cesa.org/assets/2017-Files/ESTAP-webinar-slides-1.27.2017.pdf)

[26] For examinations of the economics of electricity storage, see Sioshansi, R., Denholm, P., Jenkin, T., & Weiss, J. (2009). Estimating the value of electricity storage in PJM: Arbitrage and some welfare effects. *Energy Economics*, *31*(2), 269–277; Bradbury, K., Pratson, L., & Patiño-Echeverri, D. (2014). Economic viability of energy storage systems based on price arbitrage potential in real-time US electricity markets. *Applied Energy*, *114*, 512–519; and Salles, M. B. C., Aziz, M. J., & Hogan, W. W. (2015). *Potential Arbitrage Revenue of Energy Storage Systems in PJM during 2014*. Retrieved from http://www.hks.harvard.edu/fs/whogan/PES_paper_09_salles_final.pdf.
McConnell, D., Forcey, T., & Sandiford, M. (2015). Estimating the value of electricity storage in an energy-only wholesale market. Applied Energy, 159, 422–432. http://doi.org/10.1016/j.apenergy.2015.09.006. For a discussion of the potential role for natural gas in a low-carbon energy system, see Safaei, Hossein, and David W. Keith. "How Much Bulk Energy Storage Is Needed to Decarbonize Electricity?" 8, no. 12 (November 24, 2015): 3409–17. doi:10.1039/C5EE01452B. The idea of using electric vehicles as a kind of distributed energy storage system has also been discussed; however, analysis suggests that this would not be an economically appealing option for car owners. See Peterson, S. B., Whitacre, J. F., & Apt, J. (2010). The economics of using plug-in hybrid electric vehicle battery packs for grid storage. *Journal of Power Sources*, *195*(8), 2377–2384. Article behind paywall at http://www.sciencedirect.com/science/article/pii/S0378775309017303.

in electricity markets. The rule, however, has not yet been finalized.

Structuring and Managing Incentives for Renewable Energy

At the state and federal level, policy efforts are being made to promote the development and deployment of renewable energy—reflecting in large part concerns about climate and pollution impacts of fossil fuel energy sources. To the extent that some incentives are intended to provide temporary and relatively low-cost assistance for the development and adoption of new technologies, a central challenge is that such policies develop a kind of political inertia, and can be politically difficult to end even when the initial rationale for their adoption no longer applies. Net metering for rooftop solar is a prime example. At this point, rooftop solar has progressed far beyond its infant stage. Costs have come down tremendously, and deployment has increased to the point where the costs of the net metering subsidy are becoming an issue for other customers who are being required to subsidize an energy source from which they derive little, if any benefit, and the subsidy they are paying for does not reflect the rapidly declining cost of solar panels. At the same time, the structure of the net metering subsidy itself may be discouraging deployment of other promising technologies, such as behind-the-meter storage. Nonetheless, now that an industry has developed with a business model focused on net metering subsidies, utilities which wish to revise them face a stiff political battle. Similarly, production tax credits adopted to foster the development of the wind industry are proving politically difficult to abandon, even as the negative prices they result in cause problems for other power producers.

In fact, many economists would argue that all of the above approaches to promoting renewable energy (renewable portfolio standards, production tax credits, etc.) are strictly second or third best policy approaches, since they require policymakers to "pick winners" among technologies that might help to reduce the carbon and pollution impacts of a fossil fuel-based energy system. Many economists instead suggest that putting a price on carbon (or other pollutants) would be a more efficient approach to establishing market conditions that could allow the most promising low-carbon/low-pollution technologies to compete fairly in the marketplace. [27] In the United States, this approach has been discussed in the form of a cap-and-trade system or a carbon tax—with one of the key issues of contention being whether such a carbon price policy would replace existing renewables policies, or merely supplement them.[28]

Energy Efficiency

Like renewables, energy efficiency is an area in which policy intervention into the basic market structure may be needed in order to achieve optimal results for the U.S. energy system.

There are many ways in which the efficiency of the U.S. electricity sector can be improved. Energy efficient technologies, such as LED bulbs and lower-energy appliances, are widely available. However, in the utility sector, it may make sense to think of energy efficiency more broadly than simply in terms of household or industrial energy saving technologies. Energy efficiency can be thought of in terms of the energy system as a whole—an efficient system will be one in which customer demand and supply resources are matched up to the extent possible to avoid periods of oversupply or undersupply and to enable the utility to maximize the use of its most efficient plants. Such a system might include demand response and/or dynamic pricing.

[27] See, for example, Schmalensee, R. (2011). Evaluating Policies to Increase Electricity Generation from Renewable Energy. *Review of Environmental Economics and Policy*, *6*(1), 45–64. Retrieved from http://reep.oxfordjournals.org/cgi/doi/10.1093/reep/rer020; Morey, M., & Kirsch, L. (2014). "Germany's Renewable Energy Experiment: A Made-to-Order Catastrophe." *The Electricity Journal*, *27*(5), 6–20. Article behind paywall at http://www.sciencedirect.com/science/article/pii/S1040619014001110; Cullenward, D., & Coghlan, A. (2016). Structural oversupply and credibility in California's carbon market. *The Electricity Journal*, *29*(5), 7–14. http://doi.org/10.1016/j.tej.2016.06.006.

[28] The Obama Administration had proposed a complex Clean Power Plan set of regulations to compel reduction of carbon emissions in the power sector, as part of the effort to meet the U.S.'s obligations under the Paris Accord. The Trump Administration, while not formally repudiating the Paris Agreement, appears to be in the process of substantially weakening, if not fully eliminating, the Plan. The change in policy has led not only to litigation in the courts, but also to increased interest, especially in some academic and business circles, in the imposition of a carbon tax, something proposed by the Clinton Administration more than 20 years ago. Despite the renewed interest, the political prospects of the adoption of such a tax are dubious.

Structuring and Managing Incentives for Energy Efficiency

Increases in energy efficiency can be promoted with a range of different approaches, including consumer education, technology standards, financial support for energy efficiency improvements, demand response programs, and dynamic or time-sensitive utility pricing. To the extent that policymakers hope to use utilities in their efforts to promote energy efficiency, it is important to recognize the fact that the simple regulated utility model (still employed, for the most part, for distribution utilities, even in regions of the country in which wholesale markets have been re-structured) puts the interests of the regulated utility in conflict with the aim of promoting energy efficiency. Generally speaking, regulated utilities are compensated for providing electricity service—and receive more compensation the more service they provide. Energy efficiency reduces demand, and thus, in this regulatory model, reduces utility revenues. Although, with prompting from states and regulators, utilities may offer energy efficiency programs, these are most likely to be successful when utility interests are brought into alignment with policy drivers towards energy efficiency.

There are some energy efficiency measures that have the potential to offer savings to utilities and customers alike. For example, demand response programs, in theory, could allow utilities to provide service at lower cost, by reducing the expensive demand peaks that utilities may have to meet by calling on their most expensive marginal electricity generation (in many cases while continuing to charge flat hourly rates to customers). However, with respect to the larger aim of achieving a more efficient energy system overall through demand response and smart pricing programs, the related policy challenges are complex. In the United States, for example, FERC Order 745 required that demand response resources be paid the full locational marginal price of the energy not consumed because of their services. As some economists have pointed out, this can be thought of as a kind of double payment for demand response—first, demand response customers save money by not consuming energy, and on top of that, they are paid again for the full value of the energy they did not consume.[29] Despite a challenge to this FERC Order that went all the way to the Supreme Court, on both the pricing issues as well as on a dispute over whether the FERC or the states had jurisdiction over demand response, the Order was affirmed, and this kind of payment for demand response is required in the United States[30]

For demand response, or energy efficiency programs in general to be effective, it is vital that end users of electricity receive appropriate, time sensitive, demand reflective price signals. Large industrial customers generally do see such prices, but many commercial and most residential customers do not. There is, however, an increased interest in changing to a more dynamic pricing system for all customers, and a number of pilot programs have been put in place, and regulatory efforts are underway to broaden those efforts.

Utility Lost Revenues and Decoupling

Utilities have traditionally been concerned that increased energy efficiency would lead to lost revenues.
As a result, many utilities have been, at best, tepid in their support of energy efficiency programs. To reduce utility concerns, policy support for energy efficiency, therefore, often begins with "decoupling" utility revenues from sales volumes. Although there are many variations of decoupling mechanisms, the essential idea is that regulators set a "revenue requirement" for the utility for a few years at a time, and within that period, allow utilities to adjust their per-kWh rate to collect the full amount of the requirement, with the result that, economically, the utility should be indifferent to reductions in electricity use associated with energy efficiency.[31] In theory, decoupling removes the utility disincentive to promote energy efficiency since it is effectively compensated for not selling as many kWh as it

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[29] See *Amici Curiae Brief, District Court of Columbia Circuit, Electric Power Supply Association, et al. (June 13, 2012)* *Economists' Brief on FERC Order 745 regarding demand response compensation. (44 pages)*

[30] Another challenge for demand response programs is establishing a reliable baseline from which to measure whether demand has actually been reduced. See Chao, H. (2010). Demand response in wholesale electricity markets: the choice of customer baseline. *Journal of Regulatory Economics*, *39*(1), 68–88. Article behind paywall at http://link.springer.com/article/10.1007/s11149-010-9135-y.

[31] For more information on decoupling, see Pamela Morgan, Graceful Systems LLC, *A Decade of Decoupling for US Energy Utilities: Rate Impacts, Designs, and Observations.* Revised February 2013. Regulatory Assistance Project: http://www.raponline.org/wp-content/uploads/2016/05/gracefulsystems-morgan-decouplingreport-2012-dec.pdf.

might otherwise have sold.[32] Decoupling policies in the United States are currently widespread, but far from universal—in use in the electricity sector in 19 states.[33] Several other states have Lost Revenue Adjustment Mechanisms, which fall short of full decoupling, but do compensate the utility to some degree for revenue losses related to declining sales specifically related to energy efficiency.[34] These measure are the source of some controversy because the shifting of risks to consumers that is inherent in decoupling causes some consumer advocates to be concerned that customers will be bearing risks that are best allocated to investors.[35]

Role of Energy Service Companies

An alternative approach would be to assign energy efficiency promotion to a third party, not the utility, such as an Energy Service Company (ESCOs). There is no reason that the utility itself must be the entity responsible for educating customers about energy efficiency or promoting energy efficient technologies. Third parties, such as energy service companies, might be better suited to provide this kind of service, eliminating the need for rate adjustment mechanisms such as decoupling. To the extent that third parties can operate outside the regulated monopoly cost of service structure, they may have greater incentives and willingness to pursue implementation of new technologies and to take on potentially risky innovations in the hope of profitable outcomes.

As is explained in more detail in the 2010 paper, "Smart Grid Issues in State Law and Regulation," (co-authored by Ashley Brown and Raya Salter),[36] one of the key issues that must be considered if third parties are to play a significant role in promoting energy efficiency is the question of access to metering information and customer data and appropriate treatment of consumer privacy rights. In order to identify the most effective ways to promote consumer savings, consumers themselves (and, potentially, third party service providers) need bills that are sufficiently granular to help customers identify their major savings opportunities—at the most basic level, this means ensuring that it is clear from the bill which charges are fixed and which are subject to consumer control. Greater granularity, in the form of information about when the customer's usage tends to be highest, for instance, might also be helpful, even given relatively unsophisticated rates (as is discussed in more detail below, "smart" rates to accompany smart meters can open up greater opportunities for customer and utility savings).[37]

For third-party energy service providers (ESCOs), access to concatenated information about customer bills, and even to individual bill information, can be crucial to identifying market opportunities and targeting customers who might benefit the most from efficiency or other energy services offered by the ESCOs. However, many states recognize customer rights to privacy with respect to their personal information, and limit the right of utilities to release such information to third parties. As Salter and Brown noted in 2010, consumer privacy protections, while important, can make it harder for third party service providers to enter the market. A solution, Brown and Salter suggest, may be to clearly establish a policy of customer ownership of his or her own information and data—thus, it will be up to the customer to decide whether to share this information with third parties.[38] A customer might well choose to share this information with a company that offered the opportunity for bill savings (in theory, the customer could even sell this information.)

Meaningful Signals to Customers

As suggested above, the greatest opportunities to work with customers to realize efficiencies, either for utilities or for third party providers, depend upon pricing that

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[32] In California, in some cases, utility investment in energy efficiency is treated as capital investment for which a return may be earned. In essence, efficiency investment is treated in similar fashion as supply side investment for ratemaking purposes.

[33] Source: Center for Climate and Energy Solutions: https://www.c2es.org/us-states-regions/policy-maps/decoupling.

[34] http://aceee.org/sector/state-policy/toolkit/utility-programs/lost-margin-recovery

[35] For customers, decoupling often means paying more for each kwh consumed. If the customer is being more efficient in his/her use of energy, however, that increased per kwh charge is offset by decreased usage, so the total bill should be less. Thus, an inherent part of decoupling is to get customers more focused on their total bill, rather than the kwh charge.

[36] Ashley Brown, Esq. and Raya Salter, Esq. *Smart Grid Issues in State Law and Regulation* (September 17, 2010): http://content.energycentral.com/download/products/whitepaper_final_wcover.pdf.

[37] Brown and Salter, op cit, p. 12, reviews some of the individual state laws that govern bill transparency.

[38] Brown and Salter, 29.

accurately reflects the costs customers impose on the system ("smart" pricing to go with "smart" meters). Dynamic real-time pricing, for example, can signal to customers to reduce consumption at times of peak demand, potentially relieving the utility of the need to dispatch expensive "peaker" plants. At the same time, it is not yet clear whether customers would welcome such pricing, or respond vigorously to its price signals.[39] The potential for more dynamic consumer pricing to play a role continues to be studied in the United States. Key research questions include examining the relative costs and benefits of different pricing strategies—from simple time-of-use pricing, to more sensitive pricing, such as critical peak pricing, all the way to full dynamic pricing. Researchers and utilities are attempting to understand how responsive customers are to changes in pricing—how much of a peak demand reduction, for example, might a utility experience from a critical peak price? And how much could an alert customer hope to save in a dynamic pricing scenario?[40] One possibility is that the full potential of dynamic pricing will be best realized in conjunction with smart appliances able to respond to price signals without customer intervention.[41] Utilities are still largely in the "pilot program" phase of trying to assess the potential of dynamic pricing.

A related (and perhaps even more controversial) smart pricing mechanism is a three-part rate, which would include a fixed charge, a variable energy charge, and a demand charge, tied to a customer's peak kW demand during a given billing period. Such rates are common for commercial and industrial customers in the United States, but rare for residential customers. Those proposing such rates point out that they offer a much more accurate reflection of how customers cause costs on the system—potentially incentivizing actions and/or investments in things like battery or other storage technologies to flatten load or shift it off peak which could potentially save both customers and utilities money. Those opposing such rates often argue that they are too hard for customers to understand and respond to, and thus make it harder, not easier, for customers to use efficiency measures in order to realize bill savings.[42]

Consumer Education

Whenever new rate structures such as dynamic real time pricing and three-part rates are discussed, the question of customer education becomes important. Can good customer outreach and education measures from utilities or third parties increase the likelihood that customers will respond to these new and sophisticated rates?

There are at least two different approaches that can be taken to the idea of providing customer education suited to more sophisticated, granular rates. One approach might focus on finding ways to better provide information that would allow customers to understand and manage their electricity usage directly. Most customers do not even know what the main sources of kWh usage in their homes are—making it hard to figure out what steps might be most effective in curbing kWh usage or in flattening demand. From this perspective, as a 2009 report from the Brattle Group points out, what customers might benefit the most from is help in understanding how their use of electricity

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[39] If ESCOs have suitable access to the market, they can be invaluable in helping customers respond to the pricing signals. Indeed, given the availability of smart technology, customer responses to prices can be automated so as to require little active measures by the customers themselves.

[40] See many articles by Ahmed Faruqui on this subject, including Faruqui, A., Hledik, R., & Palmer, J. (2012). Time-Varying and Dynamic Rate Design. Retrieved from http://www.raponline.org/document/download/id/5131; Also, Joskow, Paul L and Catherine D. Wolfram. 2012. "Dynamic Pricing of Electricity." *American Economic Review*,102(3): 381-85. This presentation by Faruqui includes a rich bibliography on this topic: Ahmed Faruqui, "Technology's Role, Rates and Customers, 1985-2016." Wisconsin Public Utility Institute Madison, Wisconsin. August 16, 2016: http://www.brattle.com/system/publications/pdfs/000/005/352/original/The_past_present_and_future_of_retail_electricity_pricing_(08-08-2016).pdf?1471535256.

[41] Faruqui, Ahmad, Ryan Hledik, and Neil Lessem. "Smart by Default." Public Utilities Fortnightly (August, 2014). https://www.fortnightly.com/fortnightly/2014/08/smart-default; and
Xiaodao Chen, Tongquan Wei, Member, IEEE, and Shiyan Hu, Senior Member, Uncertainty-Aware Household Appliance Scheduling: Considering Dynamic Electricity Pricing in Smart Home" IEEE 932 IEEE *Transactions on Smart Grid* 4.2 (June 2013).

[42] This discussion is complicated by the fact that in the United States it is often associated with debates over the future of solar net energy metering. Net metering is most profitable for customers when most costs are bundled into per kWh energy charges. Thus, utilities may attempt to reduce cross-subsidies associated with net energy metering by changing billing practices to more accurately reflect the actual ways in which customer usage imposes costs on the system. Since such changes effectively represent a significant reduction in the subsidy provided to rooftop solar, they are highly controversial.

for specific appliances at specific times translates into potential cost savings.[43]

There is a second perspective on consumer education and how consumers might be most likely to interact with smart rates which may suggest a different consumer education emphasis. Even under the best of circumstances, consumers' appetite to devote time and attention to managing their energy usage may be limited. In this case, the most significant savings might come from combining smart pricing with technologies such as smart appliances, which can automate the day-to-day task of managing energy demand, within parameters set by consumers themselves. Customers may well have some reluctance to surrender control of their appliances to a third party—thus, if such technology is to gain acceptance, education efforts may have to focus on explaining the benefits to customers, and ensuring customers understand how adopting this technology can be reconciled with an ability to override the system, when desired.[44]

Shale and Unconventional Resources

In discussing the U.S. energy sector, it is important to acknowledge how radically the sector has been transformed over the past decade by the widespread adoption of hydraulic fracturing techniques to extract oil and gas from reserves not previously thought to be economically accessible. US tight oil production went from less than half a million barrels a day in 2008 to approximately 4 million barrels a day in 2014; shale gas production went from about 5 billion cubic feet per day to more than 35 billion in the same time period.[45] By 2015, shale gas production was at 53 bcf per day.[46] The resulting drop in natural gas prices has driven a large-scale shift in US electricity production away from coal and towards natural gas. Oil prices, similarly, have dropped dramatically.

What the U.S. experience may indicate for other parts of the world is not yet known. Shale resources themselves seem to be widely distributed in many parts of the world, including Latin America.[47] However, shale resources have not yet been developed to the extent seen in the United States. Is such development likely? Are there policy or other frameworks which impact the development of the shale resource? What, if anything, from the U.S. experience may be helpful in other countries? In what follows, we examine a few factors which may be relevant: the impact of concession systems, factors related to market structure and design, and the role of the financial ecosystem in enabling shale investment.[48]

Impact of Concession Systems

A combination of natural resources and what turned out to be a favorable policy environment seem to have made this shale "revolution" in the United States possible. A paper by Ilia Murtazshvili, "Institutions and the Shale Boom" summarizes how U.S. institutions contributed to the development of the shale resource, focusing on two key factors: the role of private ownership of minerals and the impact of legal institutions favorable to drilling:

> Private ownership of minerals in the United States created incentives for drillers to experiment for decades to figure out ways to profitably extract natural gas from shale, and then facilitated contracting between owners and gas companies once fracking technology emerged. Legal institutions, in particular dominance of the mineral estate (which requires

[43] Ahmad Faruqui and Ryan Hledik, *Transitioning to Dynamic Pricing.* The Brattle Group (January 27, 2009), p. 9. (http://www.brattle.com/system/publications/pdfs/000/004/715/original/Transitioning_to_Dynamic_Pricing_Faruqui_Hledik_Jan_27_2009.pdf?1378772123)

[44] See discussion in Jaquelin Cochran et al., *Market Evolution: Wholesale Electricity Market Design for 21st Century Power Systems*. Produced under the guidance of the Department of Energy and the Clean Energy Ministerial by the National Renewable Energy Laboratory under Interagency Agreement S-OES-12-IA-0010 and Task Number WFH1.2010. Technical Report NREL/TP-6A20-57477 (October 2013). http://www.nrel.gov/docs/fy14osti/57477.pdf

[45] Source: EIA: http://www.eia.gov/pressroom/presentations/sieminski_10172014.pdf

[46] Source: EIA: http://www.eia.gov/todayinenergy/detail.php?id=26112

[47] https://www.eia.gov/analysis/studies/worldshalegas/

[48] One other factor that is worth mentioning, though we do not attempt to evaluate it here, is the role that the availability of heavy equipment necessary for hydraulic fracturing may play, at least in the short term. In his 2013 paper, *The Shale Oil Boom: A US Phenomenon,* (cited below) researcher Leonardo Maugueri suggests that the availability of drilling rigs is an under-appreciated constraint on near-term shale development.

surface owners to allow the owners of mineral rights reasonable access to them), trespass decisions favorable to drillers, and compulsory pooling, further encouraged shale production. Institutional entrepreneurs, in particular lawyers and landmen, economized on transaction costs confronting gas companies, owners of mineral rights and surface owners.[49]

This discussion can be boiled down into two key points:

1. Is there any incentive for private investors to explore in order to find resources? In the United States, for the most part, drillers have an incentive to explore, because they can own what they find. This would not necessarily be the case in a country in which the State owned mineral rights, and access was determined by an open bidding process once the resource was disclosed. It is highly unlikely that anyone would explore for resources if there was only scant likelihood that successful exploration would result in a benefit for the person who made the discovery. When such legal provisions apply, thought needs to be given to what other incentives for exploration might be provided.

2. How much incentive and/or ability do surface owners have to resist shale gas drilling? In many cases, the rights of a surface owner to resist drilling may be limited, based on legal precedents (in Texas, for example) that establish that "surface owners generally have to allow reasonable access to minerals."[50] At the same time, land-owner property rights over mineral resources mean that landowners may stand to gain by allowing shale development on their property.[51]

Market Structure and Design, and the Impact of Market Regulation

The U.S. natural gas infrastructure has long been regulated, in recognition of the monopoly characteristics of natural gas pipeline and distribution systems. At times, this regulation has been extremely restrictive and extended to the commodity price as well, reflecting fears about depletion of the natural gas resource. However, since the 1980s, U.S. natural gas commodity pricing has moved increasingly from a planning model to a market-based approach.[52] Critically, a policy of "open access" to natural gas pipelines has long been in place, and is a crucial element in enabling robust competition in natural gas production, since no one company is able to monopolize access to distribution. In fact, owners of natural gas long distance pipeline companies are precluded from engaging in the commodity side of the business. Their economic interests are limited to maximizing the throughput on their system; thus, their incentive is to be open to doing business with all sellers and buyers of gas in the market place, not to leverage control of essential bottleneck facilities to their economic advantage. This policy has allowed companies which did not have the resources to construct and maintain their own pipelines to engage in hydraulic fracturing natural gas production, confident that they would be able to get any gas produced to market.[53]

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[49] Ilia Murtazshvili, "Institutions and the Shale Boom" Journal of Institutional Economics (2017), 13: 1, p. 190. Note the author contrasts these conditions with those in other countries, including Argentina: "public ownership of minerals in Argentina reduces incentives for innovation and risk-taking to the extent that people in mineral-rich lands to move from those lands (Yeatts, 1997). The delay in shale production is another example of a more general theme in the economic history of Argentine mineral extraction, which is how excessive regulation and state ownership of minerals undermines development prospects." P 201. Author's note on this issue: It is not necessarily the state's ownership of sub-surface mineral rights that poses the barrier to full exploitation to the resource. The problem is rooted in a concession process that removes all incentives for investors to engage in exploration and development. In Brazil, for example, a company which discovers the presence of shale gas has no assurance that it will gain anything for the work done, because access to the resource will be subject to a public bidding process that anyone could win. That barrier could be removed by a better designed process without changing ownership of sub-surface resources.

[50] Ibid, 197. Harvard affiliate Leonardo Maugueri points out another factor that may be important the "relatively low population density in several shale areas" in the US. See Leonardo Maugeri, *The Shale Oil Boom: A US Phenomenon.* Belfer Center for Science and International Affairs Discussion Paper #2013-05 (June 2013), p. 1. Available online at http://www.belfercenter.org/sites/default/files/files/publication/The US Shale Oil Boom Web.pdf

[51] Maugueri, 24.

[52] See the presentation, "US Natural Gas Market Evolution," by Richard P. O'Neill, in the Energy Policy Seminar at the Harvard Kennedy School, April 3, 2017. Available online at: https://www.hks.harvard.edu/m-rcbg/cepr/ONeill Presentation US natural gas market evolution.pdf.

[53] John M. Golden and Hannah J. Wiseman. "The Fracking Revolution: Shale Gas as a Case Study in Innovation Policy." *Emory*

Thanks to an open access market with plenty of competing producers, prices at natural gas wellheads are competitive; however, pipeline tariffs remain regulated, and pipeline capacity constraints can lead to congestion-related price spikes in some parts of the country.[54] Pipeline capacity may be a challenge for a number of reasons—capacity may be inadequately compensated under regulated prices. In addition, as has been seen in the United States, the development of pipelines may become increasingly difficult as proposed pipeline projects become the focus of environmental concerns.[55] Nevertheless, one element of U.S. pipeline regulation favors pipeline development. Unlike electric transmission, pipelines are under federal, not state, jurisdiction. This single entity structure makes pipeline construction in the United States far easier than the construction of electricity transmission, and likely plays a role in the thriving U.S. natural gas industry.[56]

U.S. Shale Innovation and the Competitive and Financial Ecosystem

In the case of the United States, the fracking revolution was driven primarily by independent companies, not by the major oil companies (who became involved later). In this respect, U.S. shale development benefitted from a pre-existing robust independent oil and gas sector. As Leonardo Maugueri writes in his analysis of the development of shale oil and gas:

Independent operators typically search for high-risk, high-reward opportunities with uncertain potential, whereas big oil developers pursue opportunities based on an established, more risk-averse financial framework. Also, independent operators tend to focus more heavily on generating cash flow and growth vs. stable profits over the long run. Often run by single executive or small management teams, independents understand that achieving success in their undertakings while generating cash flow enables them to raise further financing to grow their business.[57]

Maugueri goes on to suggest the importance of the relative ease of availability of financing. "The [United States'] oil and gas sector," he writes, "also benefits from the presence of domestic financial institutions, venture capital and private equity firms eager to fund independent companies and more open to forms of private financing."[58]

It would seem only logical that the development of fracking would require access to private financing, as Maugueri suggests. In fact, other researchers argue that the role that access to external capital played in the early stages of the development of hydraulic fracturing in the United States does not seem to have been critical. Researchers Wang and Krupnick examine this question in their whitepaper, "A Retrospective Review of Shale Gas Development in the United States: What Led to the Boom?" and point out that firms like Mitchell Energy (identified as a key innovator in the fracking arena), though not oil majors, were by most measures large firms with access to capital of their own. Mitchell Energy, Wang and Krupnick acknowledge, did use the capital market for funding, but they argue that "Mitchell Energy raised those funds not because of but despite its shale gas development that lost money for many years. It is not clear whether the capital market has the incentive to invest in the type of long-term risky R&D activities that Mitchell Energy undertook."[59] Mitchell Energy's shale development, they argue, was self-funded. Once the technology was more proven, Krupnick and Wang

Law Journal 64: 955-1037: http://law.emory.edu/elj/_documents/volumes/64/4/articles/golden-wiseman.pdf.

[54] Charles F. Mason, Licija A. Muehlenbachs, and Sheila M. Olmstead. *The Economics of Shale Gas Development* Discussion Paper, Resources for the Future, RFF DP 14-42 REV (November 2014; revised February 2015), p. 5. Available online at: http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-14-42.pdf.

[55] The pipeline constraints are institutional, related to the complexities of obtaining all the requisite permits to build and operate. The constraints are not because any incumbent pipelines have a legal preference. There is no monopoly concession, so competition among pipelines is not only possible, it is common. In fact, with secondary capacity markets, there is often competition for pipeline capacity on a single pipeline.

[56] For further discussion of the role of market structure in the shale gas revolution, see Paul L. Joskow, "Natural Gas: From Shortages to Abundance in the United States." *American Economic Review: Papers and Proceedings 2013* 103(3): 338-343. Available online at https://www.aeaweb.org/articles?id=10.1257/aer.103.3.338.

[57] Maugueri, p. 23.

[58] Maugueri, p. 24.

[59] Zhongmin Wang and Alan Krupnick. **"**A Retrospective Review of Shale Gas Development in the United States *What Led to the Boom?"* Resources for the Future Discussion Paper 13-12 (April 2013): 32 (http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-13-12.pdf)

acknowledge, financial firms played a significant role in financing further development.

In the United States, then, the shale gas revolution seems to have been enabled by a robust environment of independent oil and gas firms capable of some degree of self funding. An interesting and open question may be whether the need for these conditions in other countries apply, now that hydraulic fracturing is a proven technology that has attracted the oil majors. This is a question where further research and analysis may be appropriate.

It should be noted that there are environmental questions that are often raised regarding fracking. The most serious ones would appear to be related to what chemicals are injected into the ground to extract the gas, what happens to the waste resulting from fracking and to methane emissions, and how to address seismic disturbances that have occurred in some places, most notably in Oklahoma. The federal government has relatively little authority in this area,[60] so the burden has fallen on the states. While some states have done little in the area, some have begun serious efforts to impose meaningful environmental rules. Others, such as New York, have simply prohibited fracking.

Conclusion

In concluding, further discussion of the following observations may be fruitful:

- In the United States, the effort to introduce open access and greater market competition to the electricity sector has found a kind of equilibrium model in "bid based, security constrained economic dispatch with locational prices." Does this mirror the experience in Latin American countries, or are there other ways to structure electricity markets that also seem to be relatively stable?

- To what extent is the RTO structure used in Latin America? Are there any differences that might merit further discussion? Are all RTOs non-profit corporations, for instance, and/or is there a separation between RTOs and transmission and generation ownership, as in the United States? If not, are there adequate mechanisms to ensure impartial dispatch decisions?

- The U.S. electricity dispatch system seems to be trending towards ever greater levels of integration and coordination. Are there any natural limits to this, other than the physical limits of the grid itself? What is the potential for the development of dispatch systems that cross national borders? Is there a potential for greater efficiencies through cross-border dispatch integration in the Latin American context? To what extent is this already occurring?

- The impact of LMP on open access transmission, in comparison with other forms of open access, is a rich opportunity to explore the real meaning of open access and the consequences of implementing it in different ways.

- To what extent are Financial Transmission Rights in use in Latin America to manage transmission cost risks? Do opportunities exist to expand use of these financial instruments?

- Combining a regulated utility model with robust incentives for innovation is a challenge. This challenge can be partially addressed by introducing competition, to the extent possible, into the areas of the system that permit competition. Further discussion of barriers to innovation and how different jurisdictions in the United States and Latin America may have used competition or other mechanisms to combat these barriers would be helpful.

- Transparency in the United States is facilitated by the requirements for OASIS systems and independent market monitors, with questions of distribution-level transparency still largely unresolved. Further discussion of how these U.S. institutions compare to institutions intended to promote transparency in Latin American markets might shed light on opportunities to increase transparency in both the United States and Latin America.

- The full potential of smart grids and smart meters in the United States is only beginning to be

[60] The Obama Administration had proposed environmental regulations on fracking on federal lands, but the Trump Administration seems to be in the process of relaxing or rescinding them.

explored, along with the potential for "smart pricing" to encourage consumers to maximize the potential benefits these technologies offer.

- In the areas of renewable energy, the U.S. experience illustrates the potential danger of unintended consequences for market efficiency when policies such as renewable portfolio standards or demand response payment requirements disproportionately favor certain technologies. The longer such policies go on, the greater of a constituency they develop, and the harder it may be to change them—the U.S. experience suggests the importance of thinking through unintended consequences in choosing how to pursue policy goals in the areas of renewable energy and energy efficiency.

- In the United States, storage and transmission are being looked to as ways to partially address the intermittency and load shape challenges caused by the growing share of renewables in the energy mix. A comparative discussion of policies to promote renewable energy in the United States and Latin America, and of approaches to integrating intermittent energy sources, might be helpful in identifying approaches that are consistent with good electricity market design.

- The history of net metering in the United States can serve as a cautionary tale of a policy that tends to outlive its usefulness and become a drag on the efficient development and use of renewable resources. Attempts to reform net metering once it is established tend to become highly contentious, the more business models are built around this subsidy. Are there alternative, and better, means to encourage the cost-effective development of renewable resources?

- Integration of optimal energy efficiency and demand response into the electricity system faces challenges in the United States related to limited utility incentives for promoting traditional energy efficiency, coupled with required double payments for demand response resources. Utility revenue decoupling addresses some challenges, and may be usefully combined with service provision by third parties such as energy services companies. A discussion of alternative models that may be in use in Latin America would be helpful in thinking about how to best utilize these resources.

- In the U.S. context, the greatest opportunity for efficiency improvements may lie with improved consumer pricing, moving towards dynamic pricing, perhaps integrated with smart appliances, and potentially integrating three part rates to better reflect the cost of providing service to electricity customers. Discussion of experiences with implementing more advanced rates and with consumer education efforts and use of technology to assist customer response to these rates might reveal some useful lessons for how to best move towards a more sophisticated rate structure.

- The particular constellation of the market and regulatory environment in which the U.S. shale oil and gas revolution occurred raises interesting questions for other countries wishing to develop their shale oil and gas resources. Certain elements of the U.S. environment facilitated the initial exploration and investment that led to the development of fracking technologies in the United States. Is this exact constellation necessary for future fracking development in other countries? Perhaps the fact that fracking is now a proven technology means that some preconditions in the United States no longer apply. We hope that our discussion of the U.S. experience sets the stage for further discussion of shale gas and oil development in the Latin American context.

- Finally, the differing nature of concessions and licenses for exploration and development of non-conventional natural gas and oil in the United States and Latin America, and the consequences of each, are another area that lends itself quite well to dialogue and analysis.