Chapter VI

ENHANCING ELECTRICITY INTEGRATION IN NORTH AMERICA

This chapter details the interconnectivity of the United States', Canada's, and Mexico's electricity systems, as well as opportunities for enhancing integration.[a] First, the chapter outlines the existing consensus between the nations to improve integration and the regional variation in transmission capacity that exists. The next two sections explore the integration of the United States with Canada and Mexico, respectively, and provide in-depth discussions of relevant country-specific policies. The chapter concludes with possible policy options to improve integration, as well as ongoing and potential opportunities for collaboration.

[a] Due to the nature of electricity system interconnections and for simplicity of terminology, the term "North America" will be used in this chapter to refer narrowly to the continental United States, Canada, and Mexico.

FINDINGS IN BRIEF:
Enhancing Electricity Integration in North America

- Integration of the Canadian, Mexican, and U.S. power systems historically occurred by gradual, ad-hoc, and regional adjustments implemented by an array of regional, public, and private stakeholders, reflecting the complex and fragmented jurisdictions in all countries. Many opportunities for enhanced integration have included a collection of stakeholders and were pursued on a subregional basis.
- One model for power sector collaboration across national borders is demonstrated by the reliability planning under the North American Electric Reliability Corporation; however, this engagement has been limited to Canada, the United States, and the Baja California region of Mexico. The Canadian, Mexican, and U.S. governments have all made significant climate commitments and have indicated a desire to shift toward greater renewable energy penetration. In June 2016, the United States, Canada, and Mexico announced a goal for North America to strive to achieve 50 percent clean power generation by 2025. Greater cross-border integration could be a tool to maximize gains from the deployment of clean energy generation and energy efficiency, but the complexity and current asymmetry of national and subnational policy frameworks may impede implementation.
- The design of domestic U.S. clean energy policies, both at the Federal and state level, has implications for cross-border trade and continental emissions reductions. Currently, there are significant disparities between U.S. states' policies for recognition or exclusion of international clean energy imports.
- Continued study of the context and levels of integration of each subregional, cross-border interconnection will allow for a deeper understanding of policies that have shaped current levels of cross-border trade (Table 6-1).
- Canada has additional hydropower resources that could be exported to the United States to provide a reliable source of firm, low-carbon energy. There are concerns among stakeholders that increased imports of Canadian hydropower could reduce U.S. clean energy competitiveness; however, there are examples of arrangements where Canadian hydropower decreases curtailments of U.S. clean resources.
- Trade has been increasing across the North American bulk power system, but cross-border flows, especially between Canada and the United States, are now using the full capacity of existing transmission infrastructure.
- Under a low-carbon future scenario, current modeling results show that transmission with Canada becomes increasingly important for sustaining emissions reductions and has a significant impact on the generation mix in border regions.
- While many electricity system models exist for the United States (and in some cases, the United States and Canada), detailed modeling tools to explore the economic, social, and/or reliability impacts of electricity trade across all of North America are currently insufficient to inform opportunities for enhancing integration.
- While extensive integration between the United States and Canada can inform the potential for increased future U.S.-Mexico integration, these situations are fundamentally dissimilar in four main ways: (1) the lack of a dominant exporting country on the U.S.-Mexican border, (2) the different regional approaches to integration on the U.S. side, (3) the nascent regulatory framework in Mexico, and (4) the differing legal instruments for open-access transmission agreements and reliability coordination between the United States and Mexico.
- Mexico's ongoing electric utility industry reforms could have significant impacts on the future of cross-border integration. The reforms are focused on the overall goal of competitiveness, with the twin objectives of reducing electricity costs and developing more clean energy. A transition in Mexico from oil to natural gas in electricity generation could have tremendous impacts on the manufacturing sector, reducing electricity prices, boosting manufacturing output, and increasing overall gross domestic product for Mexico.

FINDINGS IN BRIEF:
Enhancing Electricity Integration in North America (continued)

- Mexico's increasing importation of U.S. natural gas could be an economic and environmental opportunity for both sides by offsetting expensive and high greenhouse gas–emitting diesel generation in Mexico and creating economic opportunities for U.S. exporters. The resulting reduction in electricity costs in Mexico could also boost overall North American competitiveness.
- The Electric Reliability Council of Texas could benefit from greater integration with Mexico through access to enhanced imports, or as a business opportunity for power exporters.
- California's ambitious clean energy policy provides an opportunity for energy exporters in Mexico, especially in the Baja California region, to supply clean energy, dispatchable power, or essential reliability services.

Cross-Border Electricity Integration

The potential for electricity integration to provide economic benefits and support the development of more modern and resilient energy infrastructure has been a long-standing theme for North American diplomacy.[1, 2] There is consensus between leaders of Mexico, Canada, and the United States that electricity integration brings great value to all three nations, but the details of planning and implementing electricity integration require the navigation of national, regional, and local interests through the engagement of a broad set of public and private stakeholders.[3]

Consensus to Enhance North American Electricity Integration

Leaders in the United States, Canada, and Mexico have publicly and repeatedly affirmed support for the concept of increasing energy integration,[4] and there is a general understanding across the continent that the benefits of cross-border electricity trade can be improved with deeper system integration. In June 2016, at the North American Leaders' Summit, President Barack Obama, President Enrique Peña Nieto, and Prime Minister Justin Trudeau signed a statement agreeing to collaborate on cross-border transmission projects in order to achieve the mutual goal of advancing clean and secure power. In particular, the United States, Canada, and Mexico announced a goal for North America to strive to achieve 50 percent clean power generation by 2025.

A number of additional recent developments make a discussion of cross-border electricity integration[b] especially relevant:

- The completion of transformational energy reforms in Mexico in the oil, gas, and electricity sectors.
- Canada's framework on clean growth and climate change, charting an accelerated path to achieve deep greenhouse gas (GHG) emissions reductions and green infrastructure development.
- The shale gas boom in the United States, which presents new opportunities for natural gas generation, as well as raises questions about land use and emissions.
- The Paris Agreement and the steps needed to implement nationally determined contributions globally.

[b] While the discussion of power sector integration has been of intense international interest, moving from aspirational objectives to actionable policy steps requires a clear, yet nuanced, definition of "integration" (or its close homologue, "harmonization"). While these terms are commonly discussed among a broad range of cross-border power sector stakeholders, there is no single definition for their use. For the purposes of this discussion, we define integration to include basic information sharing in policy making and planning, as well as the coordination of policies and decision making, often with the result of enhancing flows of cross-border trade. For the power sector, this includes any level of coordination in planning, system operations, or regulation.

- All three countries' sustained interest in stimulating strategic opportunities in clean energy development and energy efficiency.[5]
- The acceleration of the deployment of renewable energy technologies, which creates opportunities for grid management through integration.

Regional Variation in Integration across North America

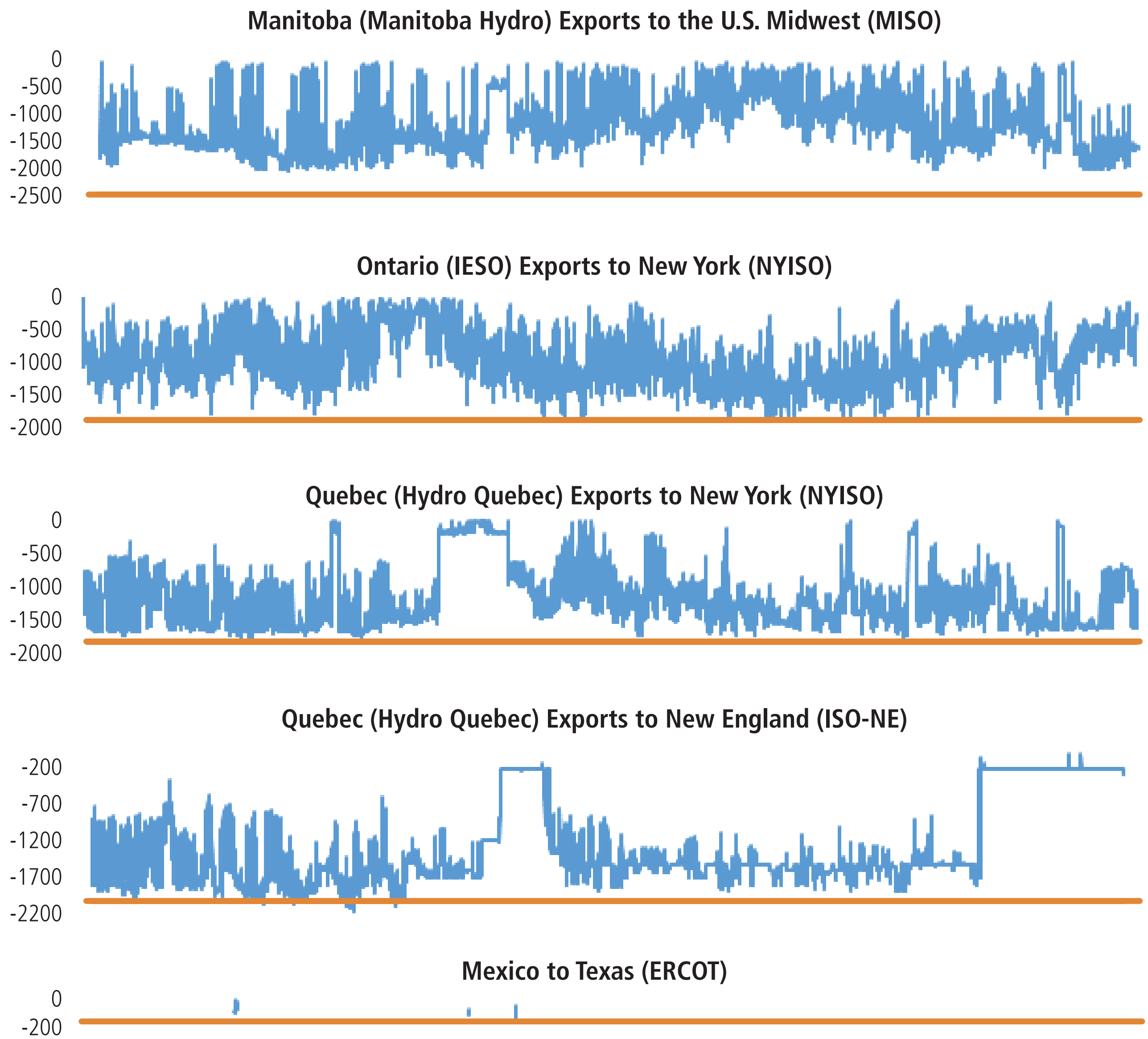
The North American electricity system is heterogeneous; operations and planning primarily take place through regional entities, and every part of the system has evolved with different characteristics and structures.[6] This leads to complex and asymmetrical jurisdictions and regulations, as well as cases in which international, cross-border coordination is sometimes greater than subregional coordination within a specific country. U.S.-Canadian integration is often greater than between Canadian provinces.[7]

A subregional lens is necessary to understand the contextual variety of the integration and interconnections between Canada and the U.S. Pacific Northwest, Midwest, and Northeast regions, as well Mexico and the southern border region with Arizona, California, New Mexico, and Texas. These different levels of integration range from physical, asynchronous interconnections geared toward emergency trade (such as in the Electric Reliability Council of Texas [ERCOT]-Mexico cross-border interactions) to extensive, synchronous interconnections that enable Canadian cross-border participation in U.S. competitive electricity markets (e.g., the Manitoba Hydro-Midcontinent Independent System Operator [ISO]). Because of this diversity, there are additional opportunities for enhanced integration that should be examined to maximize the benefits for the largest number of stakeholders for the least cost.

Additional cross-border transmission infrastructure with Canada, for example, is projected to lead to lower overall system costs in U.S. border regions, and it could enhance reliability, backstop variable renewable energy development, and enable lower overall emissions of U.S. power consumption.[8, 9] Greater cross-border planning of transmission and operations between the United States and Mexico could maximize efficiencies for commercial opportunities for U.S. generators to sell into a higher-priced market, while lowering the electricity costs paid by industrial consumers in Mexico.[10, 11] Additional electricity trading between Mexico and the United States could enhance long-term price stability and have impacts on other market factors. Coordination of the United States' and Mexico's clean energy incentives and programs, such as clean energy certificates, could lead to additional opportunities for clean energy research, development, and deployment, as well as reductions in carbon emissions.[12]

The barriers to deepening integration are also regionally nuanced. Increasing cross-border integration, especially increasing cross-border trade, raises important questions about the economic impacts of enhanced integration on domestic power generators and jobs; the reliability of power supply; the environment; costs for consumers; and increased reliance on international sources of power. In most border regions, increasing electricity flows would require the construction of additional transmission infrastructure (Figure 6-1) since current lines between the United States and Canada are operating at or near capacity, and the connections between the United States and Mexico tend to have low capacity. Developers of new infrastructure will need to strategically align planning across borders in order to overcome opposition.

Figure 6-1. Transmission Capacity and Electricity Trade across Major Interconnections, June 2015–May 2016



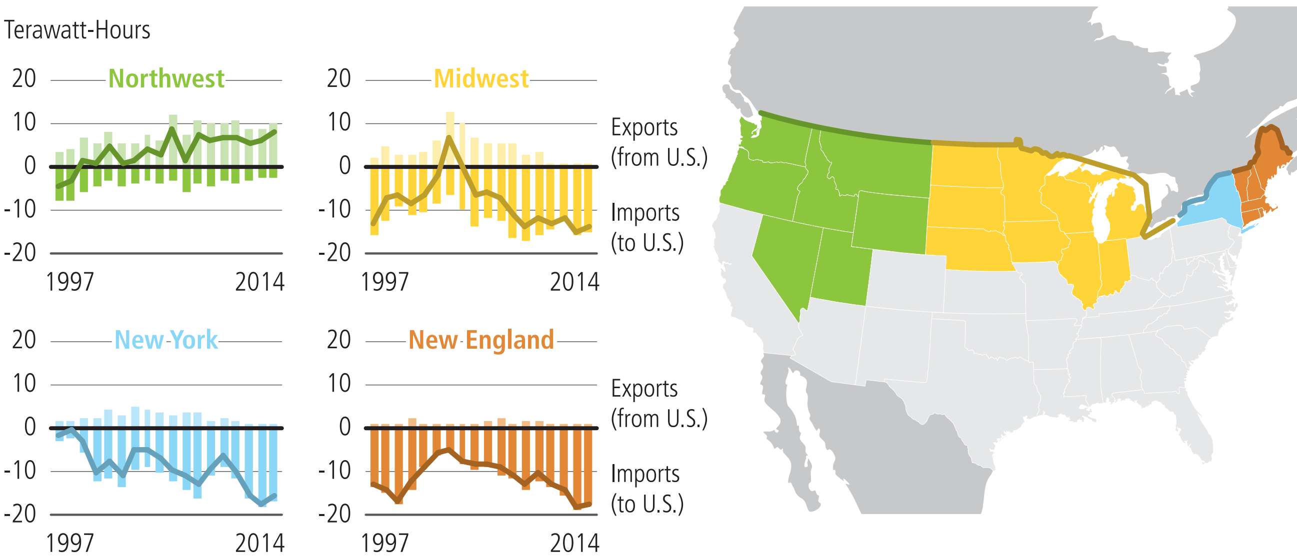
Blue lines show hourly export data from Canada and Mexico to the United States in negative megawatt-hours; orange lines indicate maximum export capacity, recorded hourly from June 9, 2015, to May 19, 2016. As the blue lines reach the orange limit of maximum capacity, transmission in that region is full and cannot be expanded on current lines. The proximity of hourly export flows to the maximum export capacity suggests that transmission lines are often fully utilized, especially in the northeastern United States. Flat-lined regions in Hydro Quebec figures are attributed to maintenance outages.

Acronyms: Midcontinent Independent System Operator (MISO), Independent Electricity System Operator (IESO), New York Independent System Operator (NYISO), Independent System Operator New England (ISO-NE), Electric Reliability Council of Texas (ERCOT).

U.S.-Canada Integration

The United States and Canada serve as a global model of highly functional, cross-border electricity coordination. Cross-border electricity trade and coordination of operations, policy, and regulatory planning are extensive, mature, and efficient, and they have led to economic and reliability benefits on both sides of the border.[13] Significant levels of cross-border transmission interconnect both countries, and electricity trade has been growing overall since 2005, increasingly dominated by flows from Canada to the United States.[14, 15] Total U.S.-Canada trade (including flows in both directions) in 2015 was 77 million megawatt-hours (MWh), accounting for a total of U.S. dollars (USD) $2.6 billion in revenues (Canadian dollars $3.4 billion).[16] With the notable exception of trade in the Pacific Northwest, which continues to be bidirectional (with the United States acting as a net exporter to Canada since 1999), in all other regions Canadian exports to the United States have significantly overtaken flows in the opposite direction (Figure 6-2).[17]

Figure 6-2. Overall U.S. Electricity Trade with Canada in Four Regions[18]



The graphs show U.S. electricity trade with Canada (1997–2014) in the Northwest, Midwest, New York, and New England. While the Pacific Northwest has been steadily increasing electricity exports to Canada, the Midwest, New York, and New England have been increasing imports over time.

Historical Overview

Recent trends in U.S.-Canada electricity trade reinforce a longer historical trajectory. Since the first electricity developments led to trade between the two countries in the early 1900s, private Canadian hydropower generators have prioritized exports to the United States over pan-Canadian trade due to a number of factors.[19] In accordance with Section 92A of the Canadian Constitutions Act of 1867, Canadian provinces have near-complete authority over their individual electricity systems. Many hydropower-producing provinces (such as British Columbia and Quebec) have vertically integrated utilities with regulated pricing structures. Markets with more diversified generation mixes (such as Ontario and Alberta), however, have implemented varying levels of restructuring, resulting in a system in which neighboring provinces often host asymmetrical market structures that aren't conducive to trade.[20] Transmission infrastructure development is determined by Canada's spatial population distribution: 75 percent of the Canadian population lives within 100 miles of the U.S. border and is clustered along the coasts.[21] Canadian hydropower producers—who have the greatest potential to increase capacity to serve other loads—have focused on extending transmission the short distances from Canadian population centers to the U.S. border rather than on more costly east-west transmission to other provinces.[c, 22]

[c] The Maritime Link Project, which links New Foundland, Labrador, and Nova Scotia, as well as discussions about exporting hydropower from British Columbia Hydro's Site C Clean Energy Project to Alberta, suggest this might be changing.

The high level of north-south integration between Canada and the United States, guided by jurisdictional, population, and geographic factors, means that cross-border coordination often surpasses east-west coordination among provinces, states, or ISOs within either country.[23] Primary interconnections link single Canadian provinces to markets in the United States: the Pacific Northwest to British Columbia; Manitoba to Midcontinent ISO; Ontario and Quebec to New York ISO; and Quebec to ISO New England.

These high levels of integration between the United States and Canada exist across the border and are facilitated in a variety of ways. For example, since 1964 the Columbia River Treaty has contributed substantially to the economic progress and safety of both countries through coordinated flood-risk management and clean, renewable hydropower within the Columbia River Basin in the Pacific Northwest. Ongoing negotiations on a new formal treaty with Canada to extend this arrangement beyond 2024 are critically important to the economy of the Pacific Northwest region, particularly for flood management and hydropower optimization.

The significant level of integration between the United States and Canada also has reliability implications. Two large-scale, cross-border blackouts—the Great Northeast Blackout of 1965 and the Northeast Blackout of 2003—among other factors, significantly shaped the current policies regarding reliability. Those events played a role in spurring the subsequent establishment of the North American Electric Reliability Corporation (NERC), the Energy Policy Act of 1992, and the Federal Energy Regulatory Commission (FERC) orders to open transmission access.[24] See the Appendix (*Electricity System Overview*) for additional detail on these events.

Benefits and Barriers to Increasing Cross-Border Electricity Trade

There is high potential to increase Canadian hydropower exports to the United States. The Canadian Hydropower Association estimates that Canada has a technical hydropower-generation potential that could more than triple current levels, up to 236 gigawatts.[25] As a resource, hydropower has several advantages: it is flexible, reliable, and cost-competitive with other sources of power, and it produces nearly zero carbon emissions.[26, 27] Hydro reservoirs can provide energy storage, and hydropower generation can be adjusted relatively quickly, making it a natural complement to intermittent resources such as solar and wind power.[28] Some dams also serve additional functions, such as managing flood control or storing potable water. Already, the climate and energy security benefits of Canadian-U.S. hydropower trade may be substantial. By one estimate, trade in hydropower between Quebec and its neighbors (New England, New York, Ontario, and New Brunswick) can be credited with 20.6 megatonnes of avoided emissions from 2006–2008.[29]

Electricity imports can serve as a cost-effective supply for wholesale power markets in the United States. The External Market Monitor of ISO New England concluded that importing electricity from Quebec and New Brunswick "reduces wholesale power costs for electricity consumers in New England."[30] Similarly, a New England States Committee on Electricity study on incremental hydroelectric imports from Canada found average annual economic benefits associated with reduced electricity prices in New England to be in the range of USD $103 million to $471 million.[31]

Cross-border trade between the United States and Canada is mature and highly integrated, but enhancing integration—especially with the objective of increasing cross-border trade—faces interrelated barriers. First, there are concerns from generators within the United States that increasing cross-border trade would have a negative impact on domestic markets and give Canadian suppliers market power.[32] In the 2000s, Canadian hydropower was viewed as one of the most cost-effective electricity sources, which presented a double-edged sword: it could lower prices for U.S. customers, but it could also outcompete U.S. generators in the natural gas and renewable energy sectors. In recent years, low U.S. natural gas prices have shifted the business case for increasing cross-border trade by reducing the extent to which imports from Canada would lower costs for electricity users.[d, 33] Continued, thorough examination of the long-term implications of integration for consumers and generators will be needed in the future.

Second, increasing electricity trade would require additional transmission capacity. While several transmission projects have already been proposed to increase capacity in the Midwest and Northeast, the complexity of these projects raises a variety of stakeholder concerns that lead to long development times and unexpected delays.[34] Concerns range from the environmental impacts of transmission infrastructure to the potential implications of greater Canadian imports on local and regional economic development.

Siting and permitting decisions are made at the state and local level, including for international transmission lines. Continued integration and transformation of the North American electricity system requires effective siting and permitting capabilities at all levels of government. Planning and permitting new cross-border transmission infrastructure, including managing ecological impacts across jurisdictions and with a wide range of domestic and international stakeholders, is uniquely challenging. State, provincial, local, and tribal governments, assisted by Federal agencies, need to build capacity to minimize safety and security consequences and protect the environment, while limiting permitting-related delays.[35, 36] Government efforts at the Federal and local levels should ensure that project developers have a clear understanding of expectations, best practices, and priorities during the permitting of cross-border transmission projects. The issuance of recent cross-border Presidential permits for the Great Northern Transmission Line[37] in Minnesota and the New England Clean Power Link[38] in Vermont are both examples of the application of collaborative principles of early engagement with stakeholders detailed in the new Integrated Interagency Pre-Application Process.[39] Additional study of and updated information on cross-border regulation can assist with establishing a clear understanding of requirements at the Federal and state levels for the permitting of cross-border transmission facilities.

Clean Electricity Development in the Cross-Border Context

Analysis of the economic and environmental impacts of increased levels of hydroelectric imports from Canada indicates that the potential for cumulative reductions in GHG emissions range from 58 million to 97 million megatonnes.[40] Many U.S states have established renewable portfolio standards (RPS), not only to reduce GHG emissions, but also to stimulate local development of clean electricity. Concerns about the negative environmental impacts of large-scale hydropower have led a number of states to adopt RPS that exclude large-scale hydropower, leading to a “non-counting” of Canadian hydropower, regardless of the positive impact such imports would have on the state’s emissions. Currently, Minnesota, Vermont, and Wisconsin are the only U.S. northern border states that have RPS that allow for the accounting of some forms of large-scale hydropower, including imports from Canada, as a clean energy resource.[41]

There are examples of Canadian hydropower supporting greater renewable energy development in the United States.[e] A 2013 Midcontinent ISO/Manitoba Hydro study explored the potential for Canadian hydropower to provide balancing for U.S. intermittent energy (primarily wind) and found that greater deployment supporting such an arrangement could provide economic and environmental benefits on both sides of the border, with annual modified production cost savings ranging from $228 million to $455 million for 2027, and annual load cost savings ranging from $183 million to $1,302 million for 2027.[42] Variations in planning and market design may require a different approach by region. In addition, lessons learned from examining the creation of economic and environmental benefits across international borders should be explored and disseminated when possible.

[d] According to the Energy Information Administration, natural gas prices for electric power fell from USD $9.26 per thousand cubic feet in 2008 to USD $3.37 per thousand cubic feet in 2015.

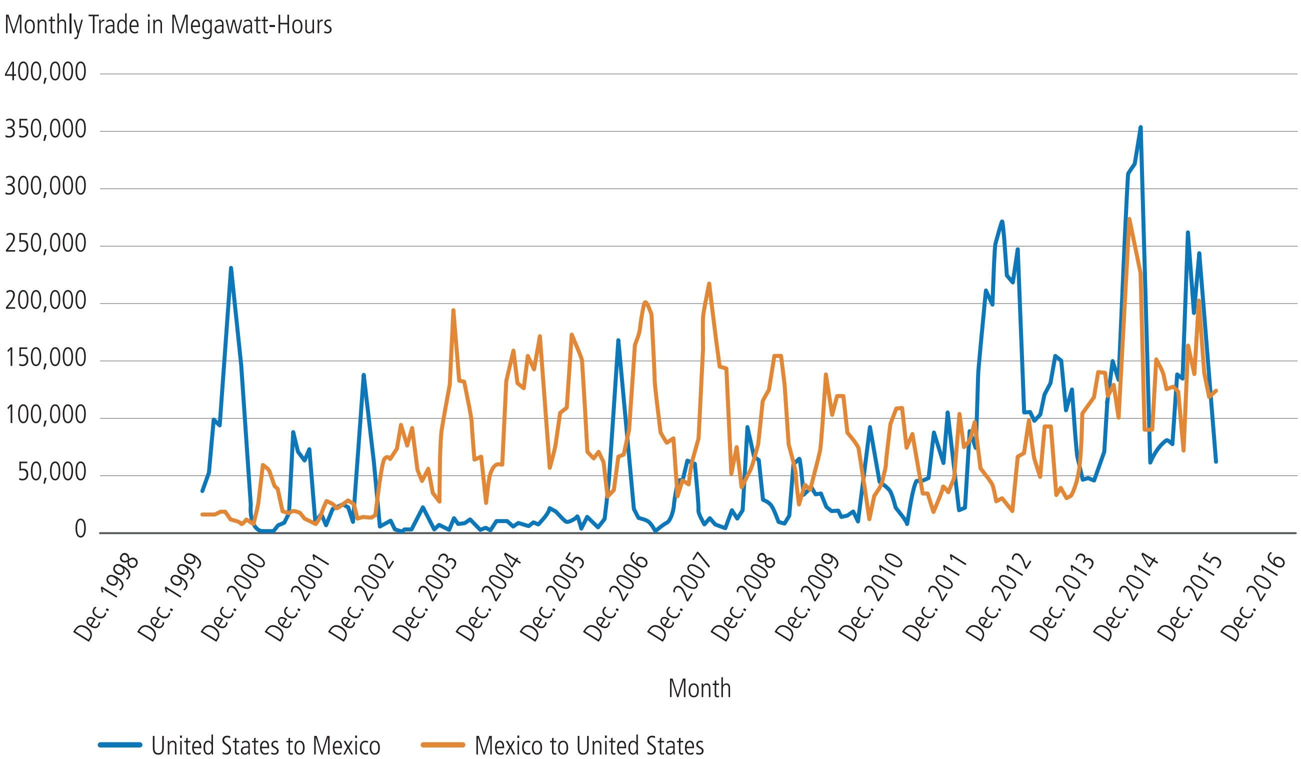
[e] This association is also suggested by the preliminary Regional Energy Deployment System projection shown for New York ISO in Figure 6-6.

U.S.-Mexico Integration

Due to a combination of historical, geographic, and resource factors, there is significantly less electricity integration between the United States and Mexico than between the United States and Canada. According to the Energy Information Administration (EIA), in 2015 the United States and Mexico traded approximately 7.69 million MWh total (compared to 77.2 million MWh traded between the United States and Canada), with the United States exporting 0.39 million MWh and importing 7.3 million MWh.[f]

A number of factors explain the differences: both Canada's and Mexico's border regions have experienced electricity shortages and lack reliable excess-generation resources[43] to export to the other; Mexico's states along the U.S. border have some of the lowest population densities in the country;[44, 45] and the border regions include areas with low (or insufficient) levels of existing transmission capacity. Two U.S. states—Texas and California—dominate the cross-border interactions with very different visions for integration. ERCOT shares the longest border with Mexico of any U.S. state, but all transmission connections between the Mexican grid and ERCOT are asynchronous, and trades are primarily for emergency backup, as illustrated in Figure 6-3. Because Baja California is not connected to the rest of the Mexican federal grid, robust California-Baja California cross-border integration may not lead to more integration opportunities in the absence of more domestic, long-distance transmission in Mexico.

Figure 6-3. Electricity Flows Between the United States and Mexico[46]



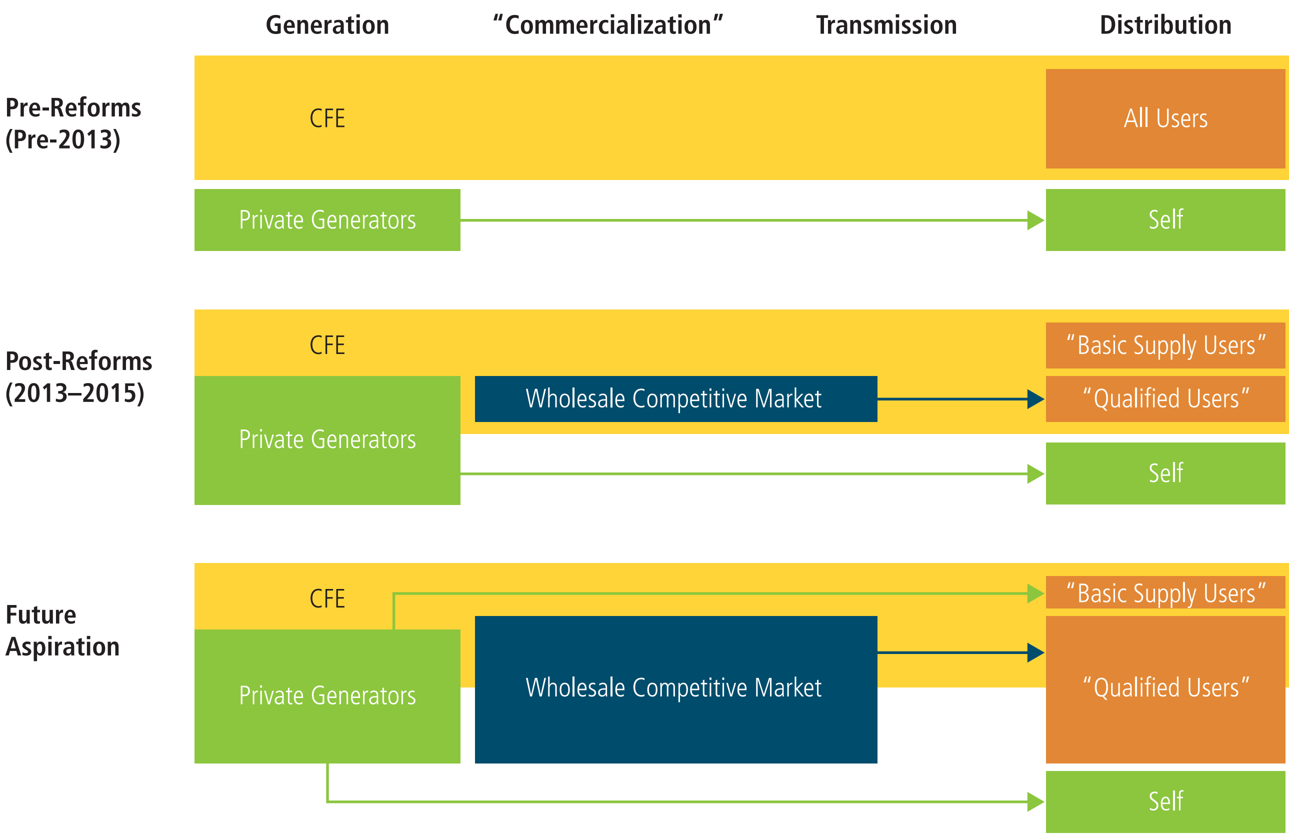
Monthly cross-border electricity trade between the United States and Mexico shows a number of differences with U.S.-Canada trade. For example, U.S.-Mexico trade occurs at lower volumes and is more sporadic and bidirectional. These are common features of trade flows that result when cross-border transmission is primarily used for emergency backup power. One important commonality, however, is that both U.S.-Mexican trade and U.S.-Canadian trade have been increasing since 2011.

[f] U.S. and Mexican estimates of U.S.-Mexico electricity trade vary significantly—a disparity that is being addressed by energy information institutions in both countries under the North American Energy Information Cooperation. Mexico's regulatory agency (Comisión Reguladora de Energía) and wholesale market operator (El Centro Nacional de Control de Energía) estimate total trade to be 4 million MWh in 2014, nearly double the EIA estimate.

Mexico's Energy Industry Reforms

Mexico's 2013 energy industry reforms, which included transformational structural reforms across the oil, gas, and power sectors, are highly relevant to cross-border electricity integration.[g] Until 2013, the Mexican Federal Electricity Commission (CFE)—the vertically integrated, state-owned utility—served as the sole producer, provider, and distributor of electricity in Mexico,[47] and private participation in the sector was reserved for the state except in limited situations (small power production, cogeneration, and independent power production). The existing framework, however, faced significant stress in the 1990s and early 2000s, caused by a mixture of external and structural factors, including high energy prices, low industrial competitiveness, government subsidization of electricity, lagging domestic fossil fuel production, and underinvestment in the power sector. Projected growth of power demand over the next decade led the government to pass extensive energy reforms in 2013, followed by a series of implementing laws that unbundled CFE and established a new wholesale electricity market to foster competition with private-sector participation (Figure 6-4).

Figure 6-4. Structural Changes Following Mexico's Energy Industry Reforms

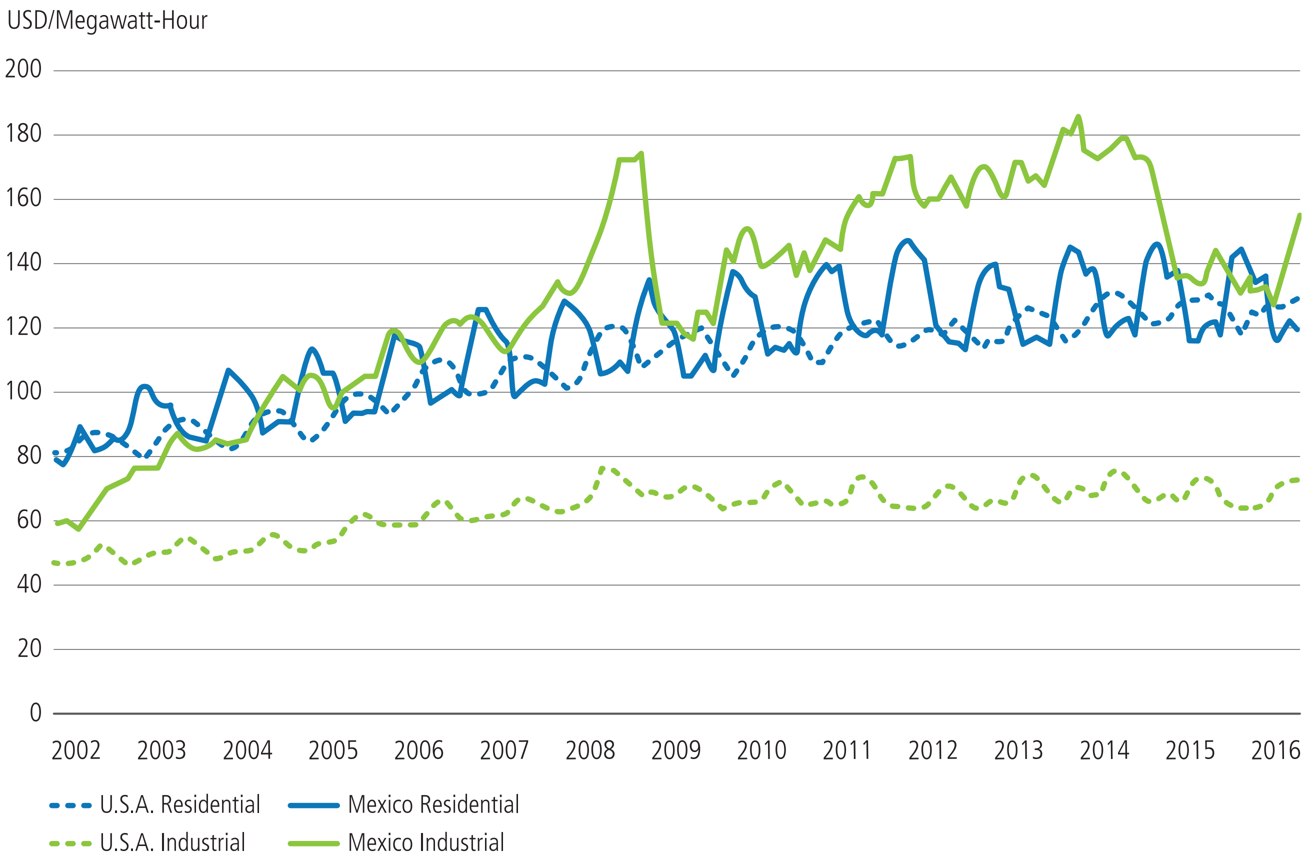


This figure is a simplified schematic, showing the adjustments in the Mexican power sector, pre-reforms, post-reforms, and future aspirations. Pre-reforms, CFE was vertically integrated and responsible for the generation, commercialization, transmission, and distribution of electricity to nearly all users, with exceptions for some forms of self-generation. The reforms created a wholesale competitive electricity market in which private generators can participate and divided users into "basic supply" users (those who consume under a given threshold and continue to receive direct service from CFE) and "qualified users" (those who consume over that threshold and are serviced by the wholesale competitive market). Over time, the wholesale market is intended to supply the majority of consumers. CFE continues to maintain control over transmission and distribution post-reforms.

[g] Unlike U.S. and Canadian power sector governance, which defers a number of authorities to state and provincial governments, Mexico's federal government is more centralized and also has near-complete authority in the power sector.

Under the new framework, the private sector is now free to participate in all aspects of the generation and sale of electricity, while CFE maintains physical control of transmission and distribution infrastructure and remains the sole provider to residential users with regulated tariffs, and the National Energy Control Center is now the ISO in charge of the operational control and administration of the new wholesale electricity market.[48] Many power sector stakeholders have called the reforms groundbreaking and admirable, including for reducing the strain of electricity consumption costs on industry in Mexico (Figure 6-5).[49]

Figure 6-5. Industrial and Residential Electricity Rates in the United States and Mexico, 1993–2013[50]



Different policies regarding industrial electricity and residential tariffs in the United States and Mexico, as well as different electricity generation sources (over the given period, Mexico used greater diesel/heavy fuel oil-fired generation, while the United States was more reliant on coal and natural gas) have led to a significant differential between U.S. and Mexican electricity rates. Of particular note, industrial rates in Mexico were slightly less than double U.S. rates in 2013, which impacts Mexican industrial competitiveness. Rates include government subsidies to Mexican residential consumers.

Reforms are focused on the overall goal of competitiveness, with twin objectives of helping consumers pay less for electricity and supporting cleaner electricity.[51] Currently, the industrial sector in Mexico faces costs per megawatt-hour of electricity that are almost double electricity costs in the United States, making production and goods more expensive for all of North America. In seeking lower energy prices for its consumers, Mexico is focusing on switching from fuel oil and diesel-fired generation in the power sector to natural gas (in part through greater imports from the United States[52]), reducing transmission and distribution losses (estimated at 16 percent of total generation in 2010), and increasing renewable energy deployment.[53] The impacts for Mexico's northern border region, specifically, could be significant as the region includes a number of industrial centers in Ciudad Juárez, Matamoros, Mexicali, Nogales, Nuevo Laredo, Reynosa, Tecate, and Tijuana.[54] One economic analysis estimates that transitioning from oil to natural gas for electricity production could have tremendous impacts on the manufacturing sector, where it could reduce electricity prices by 13 percent, boost manufacturing output by up to 3.9 percent, and increase overall gross domestic product by up to 0.6 percent.[55, 56]

Mexico is already seeing reductions in electricity prices; though the recent low oil and natural gas prices are likely a contributing factor, this trend is also likely to be stimulated by the reforms. From December 2014 to December 2015, electricity rates fell between 30 percent and 42 percent for industry. The wholesale electricity market also began to operate in January 2016, and renewable electricity generation capacity increased by 8.5 percent from 2013–2014 alone.[57] However, a differential in prices still exists: in the first 6 months of 2016, average wholesale prices in most locations of Mexico ranged from $48/MWh to $60/MWh,[58] while in Texas the ERCOT North 345-kilovolt peak wholesale prices over the same period were $22/MWh.[59]

Projected Actions and Potential Opportunities

Mexico's energy industry reforms may shift the cost-benefit analysis of enhanced integration in meaningful ways: these reforms were intended to increase generation in northern Mexico (including a number of industrial centers), stimulate private-sector investment in the power industry, lower energy costs, increase flows of natural gas from the United States, and increase renewable energy and energy efficiency deployment. All of these objectives could have implications for the attractiveness of increasing cross-border coordination and electricity trade.

According to analysis done by EIA, Mexico plans to build an additional 57 gigawatts of generation capacity from 2016 to 2030 and double natural gas imports from the United States from 2013 to 2018,[60] which will lead to a decline in electricity subsidies. The Program for Development of the National Electricity System, an annual report known by its Spanish acronym "PRODESEN," also demonstrates the intent to increase transmission capacity within Mexico, with some developments that could have impacts on cross-border trade, including connection of the Baja California Peninsula to the Mexican federal system by 2021 and construction of a new 150-megawatt asynchronous connection between Nogales, Sonora, and Arizona.[61, 62] The Mexican government is also studying the possibility of a larger east-west transmission line along the U.S. border, with the objective of enhancing transmission capacity in northern Mexico and facilitating cross-border trade.[63] Policy, regulatory, infrastructure, and economic changes in Mexico may lead to a number of other new opportunities.

The smart grid is a key area of focus; the PRODESEN report supports a smart grid program every 3 years to evaluate projects for the integration of new technologies into transmission, new wide-area monitoring systems, diagnostics and protections coordination using phasor measurements, and automation and modernization of substations. These investments will likely stimulate interest among U.S. generators to export electricity to Mexico, increase potential for flows from Mexico to the United States to supply U.S. demand for clean energy and essential reliability services, expand trade flows in both directions to enhance reliability, improve cooperation to stimulate clean energy development, and reduce GHG emissions. Mexico's increasing importation of U.S. natural gas has been and will remain an economic and environmental opportunity for both sides by offsetting expensive and high GHG-emitting diesel generation in Mexico and creating economic opportunities for U.S. exporters. The resulting reduction in electricity costs in Mexico could boost overall North American competitiveness and opportunities to integrate supply chains.[64]

Mexico has also established a program of clean energy certificates, which bears a resemblance to California's renewable energy credit system. Mexico's Transition Strategy has a significant focus on promoting clean technologies and fuels, with the goal of reaching 35 percent clean energy generation by 2024.[65] A variety of tools, such as the Clean Energy Zone Atlas, will help Mexico plan for the development of clean energy power plants and the expansion of the grid, similar to the Competitive Renewable Energy Zones in Texas. Two long-term clean energy auctions in 2016 produced record-low prices for energy, capacity, and clean energy certificates, and in the first auction, contracts were awarded with an average certificate price of USD $47.76; these projects will start operations in 2018. In the second auction, renewable projects—including solar, wind, geothermal, hydro, and combined-cycle natural gas (only for capacity)—produced three record-low prices for Latin America: a wind price of $32/MWh and a solar price of $27/MWh. These recent auction results indicate the opportunities in Mexico for renewable energy development. There are even instances where projects in Mexico qualify for California's RPS—the Energia Sierra Juarez project, a wind farm constructed miles from the California border, is one example of a Mexican project that has received certification to qualify. The Mexican government is fully committed to capitalizing on these opportunities, and its federal authority is sufficient to implement widespread changes.

There are several challenges raised by enhanced cross-border electricity integration with Mexico. Mexico's sector continues to experience high levels of technical and non-technical losses,[66] and it will need significant investments to improve system functionality to achieve greater efficiencies, especially in a scenario that includes significant increases in power trading with the United States' bulk power system. Mexico has different protections for open access to transmission from the United States and Canada. Though rules exist for access to government-owned transmission in Mexico, these are dissimilar to FERC Order Nos. 888 and 890.[67, 68] Additionally, both sides of the border have experienced power shortages in the past decade, suggesting that at this time neither border region has developed significant and reliable excess power to sell to the other on a firm basis.

The limitations of trade between Texas and the rest of the United States, vis-à-vis the Federal Power Act, do not apply to, and therefore are not a limitation on, ERCOT's electricity trade with Mexico. Though ERCOT has maintained a more isolated domestic trade strategy for electricity, the same Federal Power Act issues that drive these policies should not impact ERCOT-Mexico trade in electricity. The combination of challenges to trade, even though ERCOT shares the longest border with Mexico of any U.S. state, suggests that it will take a very compelling business case to enhance cross-border flows.

Emerging Integration Opportunities across North America

The extensive electricity integration that already exists between the United States and Canada, and the potential to increase existing integration between the United States and Mexico, suggest that North America has much to gain from collaborative planning, strategy, and cooperation in the power sector.

Carbon Trading and Pricing to Address Emissions in Mexico and Canada

In recent months, the federal governments of both Canada and Mexico have announced plans for new policies to address carbon dioxide emissions (Table 6-1). For several years, provinces and the private sector have pursued various forms of carbon accounting, charging, and trading. The electricity sector has and will play an important leading role in reducing economy-wide emissions of carbon dioxide. Given the highly integrated nature of the U.S.-Canada electricity system and the increasingly integrated state of the U.S.-Mexico electricity system, it will be important to explore the effects of implementing new federal carbon reduction policies across North America.

Subregional carbon markets are present all around the United States, including in states that border Mexico and Canada. The Regional Greenhouse Gas Initiative was the first mandatory carbon market in the United States, and it includes a cap-and-trade program for carbon dioxide emissions from power generators in the Northeast, Delaware, and Maryland (see Chapter III, *Building a Clean Electricity Future*, for additional detail). California and Quebec have had linked carbon markets since 2014, and Ontario will join those markets in 2018. Mexico and the province of Manitoba are also considering joining. As these arrangements evolve, the implications of these new markets for carbon trading should be examined further.

Table 6-1. New Carbon Trading and Pricing Policies in Canada and Mexico Are a First for North American Federal Governments

Canada	Mexico
	
Most of Canada's provinces have implemented initiatives to reduce carbon dioxide emissions from the power sector,[h] and 80 percent of Canadians live in a province where there is pollution pricing.[i] In September 2016, the federal government announced a "floor" carbon tax that will be introduced in 2018 at \$10/ton of carbon. Under the federal program, the carbon price will rise \$10/ton per year until 2022, when the price will freeze at \$50/ton. Provinces have considerable implementation flexibility. The price can be in the form of a specific tax or levy, or as a cap-and-trade program, provided provinces set emissions caps that correspond to the expected reductions from the carbon price. The carbon tax will be revenue-neutral for the federal government, which will return funds to provinces from federally imposed carbon taxes. Any province can also levy the carbon tax and collect revenue itself, without involving the federal government, to meet the carbon pricing requirement.[j, k] A number of provinces, including British Columbia,[l] Alberta,[m] Ottawa, and Quebec,[n] are already in compliance with a carbon price for 2018, though the rising federal price of carbon will necessitate additional action from all provinces by 2022.	Mexico introduced a carbon tax on the use of fossil fuels in 2014. The initial price on carbon was set at U.S. dollars \$3.5/ton of carbon.[o] In November 2016, Mexico launched its first federal initiative to deal with carbon, a pilot project with voluntary participation for study purposes of Mexico's new cap-and-trade program. The information will inform implementation of the 2018 launch of Mexico's new cap-and-trade program. The program is being guided by the Secretariat of Environment, the Mexican Stock Exchange, and the Mexican Carbon Platform, a private trading platform established in 2003. The platform involves voluntary participation of approximately 60 companies from various industries, including steel, cement, and chemicals, which combine to generate 70 million tons of carbon dioxide annually. Historically, the state of Baja California has been involved in California's carbon trading and clean energy policies for several years. To formally launch the cap-and-trade program in 2 years, Mexico will need to establish a cap on greenhouse gas emissions and create a program for monitoring and verification.[69, 70]

The electricity sector has and will continue to play an important leading role in reducing economy-wide emissions of carbon dioxide across North America. This table briefly describes recent announcements and actions by the federal governments of Canada and Mexico to address carbon dioxide emissions from the electricity system.

[h] Prince Edward Island has no current targets or initiatives in place; the territory of Nunavut is implementing climate adaptation strategies that do not address power generation. All other provinces and territories either have some form of emissions-reduction target and/or carbon pricing in place, including but not limited to mass-based targets, cap-and-trading, and RPS. Two territories, Northwest Territories and Yukon Territory, have voluntary energy efficiency targets in place for households and businesses that will reduce emissions from the power sector.

[i] "Government of Canada Announces Pan-Canadian Pricing on Carbon Pollution," Government of Canada, Ministry of Environment and Climate Change, October 3, 2016, http://news.gc.ca/web/article-en.do?nid=1132149.

[j] The Canadian Press, "5 things to know about Canada's carbon pricing plans," *Toronto Star*, October 3, 2016, https://www.thestar.com/news/canada/2016/10/03/5-things-to-know-about-canadas-carbon-pricing-plans.html.

[k] Bruce Campion-Smith, "Justin Trudeau's Liberals unveil plan to price carbon," *Toronto Star*, October 3, 2016, https://www.thestar.com/news/canada/2016/10/03/justin-trudeaus-liberals-unveil-plan-to-price-carbon.html.

[l] British Columbia currently has a carbon tax of \$30/tonne.

[m] Alberta will levy a carbon tax on fuels at a rate of \$20/tonne beginning in January 2017. One year later, the levy will increase to \$30/tonne.

[n] Carbon was trading at \$17 Canadian/tonne in May 2016 for the cap-and-trade market that includes Quebec and will include Ottawa (according to the International Carbon Action Partnership).

[o] Government of Mexico, Tax on Fossil Fuels, enacted in the Special Tax for Production and Services Law, Congress of Mexico, 2014.

Improving Grid Security and Reliability

Protecting the grid against vulnerabilities is a shared responsibility across North America. Most recently, the United States and Canada have agreed upon goals to (1) protect today's electricity grid and enhance preparedness, (2) manage contingencies and enhance response and recovery efforts, and (3) build a more secure and resilient future electric grid.[71] The joint U.S.-Canada Grid Security Strategy promotes improvements to information sharing, vulnerability assessment, emergency response and continuity, and management of new and evolving risks from grid technologies and design.[72]

The United States and Canada have developed respective national action plans to address and improve grid security. Going forward, there are key areas of mutual interest where joint cooperation can continue to grow between the United States and Canada. These include the Department of Energy (DOE) and Natural Resources Canada working in coordination with the Department of Homeland Security and Public Safety Canada to:

- Inform and support the private energy sector in response to a significant cyber incident
- Improve tools, frameworks, protocols, and methods for information sharing, risk assessment, and situational awareness
- Coordinate with existing table-top exercise formats
- Develop standardized curricula and training materials for utilities to educate their workforces on protection against threats, including cybersecurity.

Coordination of grid security efforts can lead to a more proactive approach to addressing emerging threats across North America. As Mexico's interconnections with the United States grow in number and capacity, it will be important for ongoing discussions of grid security goals and objectives to be informed by Mexico's experiences and perspective.

Mexico is working closely with NERC to achieve well-interconnected, secure, and stable electricity grids. Currently, an interministerial body (the Ministry of Energy, the System Operator, and the Regulatory Commission) has been set to produce a first version of Mexico's proposal of a memorandum of understanding with NERC. Along with this proposal, the group is working very closely with the staff of DOE, FERC, and the Western Electricity Coordinating Council to ensure consistency with other specific agreements.

As more interconnections are planned and built between the United States, Canada, and Mexico, the North America bulk power system must not only remain secure, but reliable as well. High-level cooperation between all three countries on energy issues should maintain a focus on the shared goal of a reliable electricity system for the continent. From coordination on high-level principles for reliability, to modeling and analysis to inform operations of the future bulk power system, cooperation across North America on reliability will complement efforts to improve security and ensure economic competitiveness.

Policy Options for North America

There are a variety of policy options that all three countries, and the United States individually, can take to support targeted action to enhance integration: (1) engagement—often high level and internationally through bilateral and trilateral dialogues and other cooperation mechanisms; (2) analysis—both cooperative and independent—carried out through working groups and projects; and (3) policy-level actions—primarily executed by domestic federal and state entities. Specific recommendations are described more thoroughly in Chapter VII (*A 21st-Century Electricity System: Conclusions and Recommendations*).

Additionally, while many detailed electricity sector modeling tools exist for the United States (and in some cases, the United States and Canada), modeling tools capable of analyzing the economic, environmental, social, or reliability impacts of electricity integration throughout North America are relatively coarse. Improved models would lead to more informative and useful results to enable better stakeholder decisions.

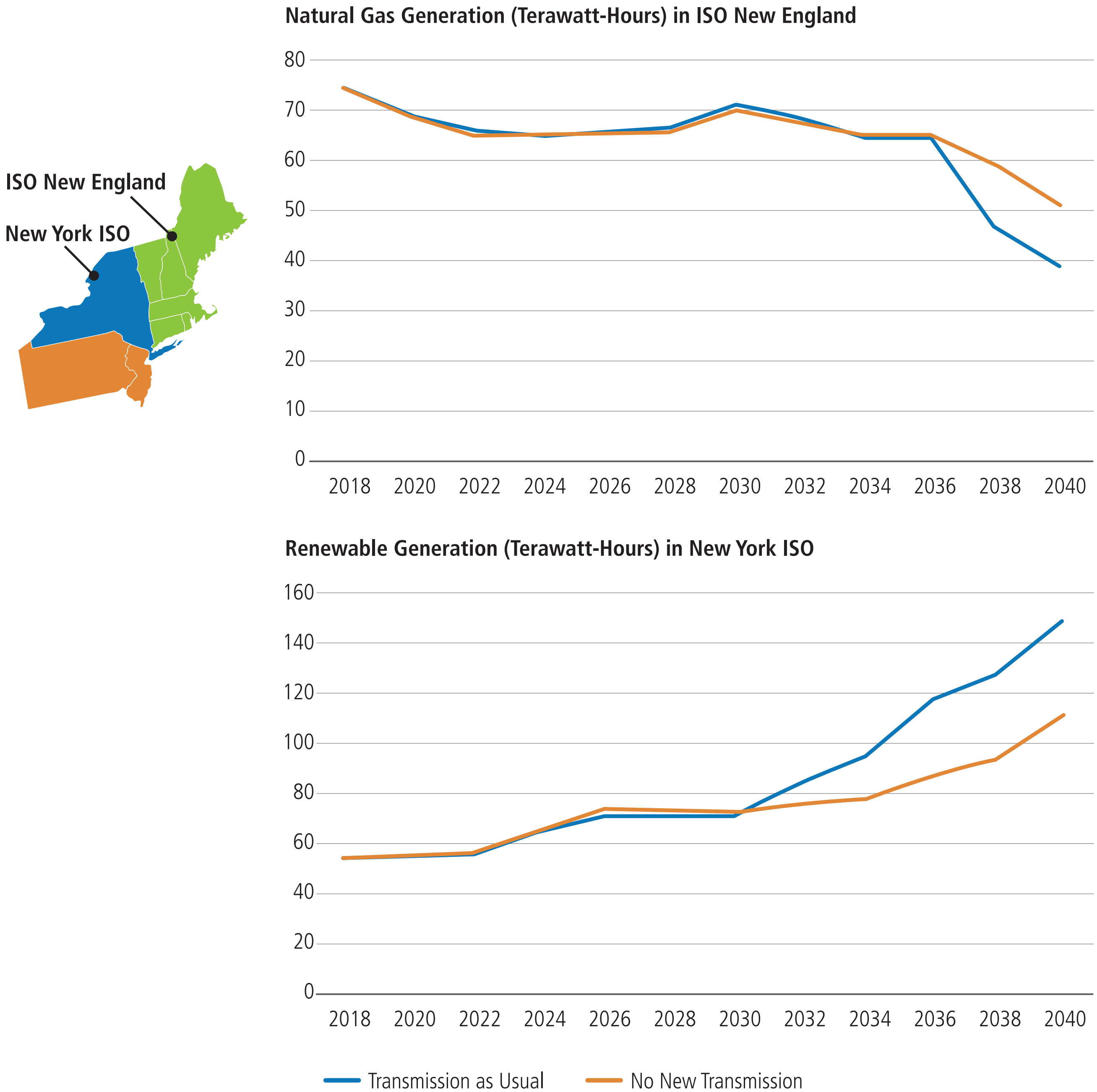
Analysis of Cross-Border Electricity Policy

While there is a diversity of power sector modeling tools to analyze U.S. grid or market operations at varying levels of detail and accuracy, such tools do not yet exist at a robust level for the combined power system of Canada, Mexico, and the United States, limiting the ability of modeling to estimate costs and benefits of increasing cross-border trade.[73] One exception is the Regional Energy Deployment System (ReEDS), which does represent both the United States' and Canada's power systems.[74] Sample, preliminary analysis from this model is highlighted in Figure 6-6. DOE's Office of Energy Efficiency and Renewable Energy is working with the National Renewable Energy Laboratory to expand this model to Mexico in cooperation with the Mexican Secretariat of Energy and the Mexican National Energy Control Center. Final results will be used to understand the implications of a variety of U.S.-Mexican energy scenarios, inform decision making about renewable energy integration and cross-border energy markets, and establish the analytical framework for long-term strategic thinking about a shared North American energy future.

DOE, Natural Resources Canada, and Mexico's Secretariat for Energy are also supporting a 3-year effort through the North American Renewable Integration Study (NARIS) to share data and enable modeling and analysis of coordinated planning and operations across North America under high-market-penetration renewable energy scenarios. The ReEDS United States, Canada, and Mexico models will be used to inform the NARIS study scenarios. The NARIS study will be completed in 2018.

Though not scenario-based, complementary qualitative analyses (Table 6-2) can allow policymakers to understand the current status of integration and the relevance of specific factors to impact cross-border trade opportunities.

Figure 6-6. Possible Long-Term Impacts of Cross-Border Transmission on Regional Generation Mix in the United States, 2018–2040



Under a low-carbon future scenario, results from ReEDS show that transmission with Canada becomes increasingly important for sustaining emissions reductions and has a significant impact on the generation mix in border regions. In ISO New England, greater cross-border transmission capacity reduces domestic natural gas generation. In New York ISO, additional transmission capacity with Canada is associated with an increase in domestic renewable generation.

Table 6-2. Analysis of Variables That Have Led to Current Levels of Cross-Border Trade in Cross-Border Trade Relationships

Criteria	Pacific Northwest	Midwest	New York ISO/Can	ISO New England/ Quebec	California-Baja	ERCOT-Mexico
Integration enhances electric reliability	Sufficient for needs in an expanded trade scenario	Sufficient for needs in an expanded trade scenario	Sufficient for needs in an expanded trade scenario	Sufficient for needs in an expanded trade scenario	Sufficient for current needs	Moderately available; expansion/adjustment already in process
Coordination in cross-border operations and planning	Sufficient for current needs	Sufficient for needs in an expanded trade scenario	Sufficient for current needs	Sufficient for current needs	Sufficient for current needs	Present but insufficient for current needs
Economic opportunities stimulate greater cross-border trade flows	Sufficient for current needs	Sufficient for current needs	Sufficient for current needs	Sufficient for current needs	Sufficient for current needs	Moderately available; expansion/adjustment already in process
Regulatory certainty: transmission access agreements	Sufficient for current needs	Sufficient for current needs	Sufficient for current needs	Sufficient for current needs	Moderately available; expansion/adjustment already in process	Present but insufficient for current needs
Sufficient transmission capacity	Sufficient for current needs	Moderately available; expansion/adjustment already in process	Moderately available; expansion/adjustment already in process	Moderately available; expansion/adjustment already in process	Moderately available; expansion/adjustment already in process	Sufficient for current needs
Clean energy/climate incentives stimulate cross-border trade	Not present, N/A	Moderately available; expansion/adjustment already in process	Not present, N/A	Not present, N/A	Moderately available; expansion/adjustment already in process	Not present, N/A

- Sufficient for needs in an expanded trade scenario
- Sufficient for current needs
- Moderately available; expansion/adjustment already in process
- Present but insufficient for current needs
- Not present, N/A

The analysis, done by DOE's Office of Energy Policy and Systems Analysis, demonstrates the variables that have contributed to differences in the level of cross-border integration observed in each cross-border interaction, with robust cross-border integration between the United States and Canadian counterparts, and less developed integration between the United States and Mexico. Cross-border ties with Arizona and New Mexico were not included due to their small capacity.

Table 6-2 assesses the degree to which cross-border electricity trade in each region has met the criteria that must be present in order to increase international trade in electricity. Cross-border trade in electricity must provide for customer demand across the border, enhance reliability, provide sufficient transmission capacity, coordinate cross-border operations and planning, and provide regulatory certainty. Additionally, incentives for clean energy can also influence cross-border trade and have been included in this table. Looking at the assessment, it is clear that some key factors required for enhanced integration are still emerging on the U.S.-Mexico border, while supporting factors for cross-border trade in regions shared by the United States and Canada are already in place. This table points also to areas for further work and cooperation among regional stakeholders and governments, including for transmission capacity development.

The extraordinary complexity of the North America bulk power system means that policymakers and other stakeholders will require robust and extensive analysis to understand the implications of any specific action. Three main elements comprise what is necessary for analysis:

- Access to consistent energy information and data from all three countries (including information regarding generation, transmission, and distribution functions and expansion plans, electricity flows, and pricing).
- Access to information on existing policy, regulatory, and operational features of the power system at the national, state/provincial, ISO, and local levels.
- Rigorous power sector modeling capabilities that can provide estimates of economic, environmental, social, and operational benefits and costs at varying levels of detail.

Descriptions of analyses that will enhance North American electricity integration can be found in Chapter VII (*A 21st-Century Electricity System: Conclusions and Recommendations*).

Electricity Engagement between Canada, Mexico, and the United States

Engagement between Canada, Mexico, and the United States will serve to align national objectives. For example, trilateral and bilateral dialogues or mechanisms for cooperation, including the North American Leaders' Summit, North America Energy Ministers' Meetings, and the Working Group on Climate Change and Energy; trilateral and bilateral memoranda of understanding; the U.S.-Canada Regulatory Cooperation Council; and bilateral dialogues with Canada (U.S.-Canada Clean Energy Dialogue, U.S.-Canada Energy Consultative Mechanism) and Mexico (U.S.-Mexico High Level Economic Dialogue, U.S.-Mexico Task Force on Clean Energy and Climate Policy, U.S.-Mexico Bilateral Framework on Clean Energy and Climate Change) provide a comprehensive set of diplomatic and working group opportunities for leaders to provide a high-level commitment to action, establish national priorities, establish working groups and task forces to explore specific topics in greater detail, and coordinate developments internationally. Additionally, meetings of leaders at which commitments are made, including the recent goal of 50 percent clean power generation by 2025 for North America, can provide an important forum for engagement. All of these efforts can help to align development and technical assistance efforts, expand networks beyond governments to include key stakeholders from the private sector and other relevant power sector institutions or multilateral development institutions, and stimulate new interest in analysis of other policy options.

Descriptions of recommended engagements to enhance North American electricity integration can be found in Chapter VII (*A 21st-Century Electricity System: Conclusions and Recommendations*).

Specific Policy-Level Actions

Finally, at the most granular level, specific policies can be implemented, strengthened, or adjusted to support enhanced integration. These policy actions range from domestic financial incentives that affect cross-border trade (e.g., tax policy, export tariffs, and clean energy incentives) to regulatory frameworks that could be improved to ensure more coordinated yet robust functioning of existing governance (e.g., permitting processes).

Descriptions of policy actions that will enhance North American electricity integration can be found in Chapter VII (*A 21st-Century Electricity System: Conclusions and Recommendations*).

Endnotes

1. Energy Information Administration, *Memorandum of Understanding among the Department of Energy of the United States of America and the Department of Natural Resources of Canada and the Ministers of Energy of the United Mexican States Concerning Cooperation on Energy Information* (Washington, DC: Department of Energy, December 2014), https://www.eia.gov/special/trilat/pdf/DOE-NR_Canada-United_States_Mexican_MOU_Energy%20 Information_12-15-2014.pdf.

2. "Memorandum of Understanding among the Department of Energy of the United States of America and the Department of Natural Resources of Canada and the Ministers of Energy of the United Mexican States Concerning Climate Change and Energy Collaboration," Natural Resources Canada, last modified February 12, 2016, https://www.nrcan.gc.ca/energy/international/nacei/18102.

3. Alan J. Krupnick, Daniel Shawhan, and Kristin Hayes, *Harmonizing the Electricity Sectors across North America: Recommendations and Action Items from Two RFF/US Department of Energy Workshops* (Washington, DC: Resources for the Future, 2016), http://www.rff.org/files/document/file/RFF-DP-16-07.pdf.

4. "Memorandum of Understanding among the Department of Energy of the United States of America and the Department of Natural Resources of Canada and the Ministers of Energy of the United Mexican States Concerning Climate Change and Energy Collaboration," Natural Resources Canada, last modified February 12, 2016, https://www.nrcan.gc.ca/energy/international/nacei/18102.

5. United Mexican States' Energy Transition Law (2015), Article 3, XXIX "Goals," accessed December 29, 2016, http://dof.gob.mx/nota_detalle.php?codigo=5421295&fecha=24/12/2015.

6. EPSA Analysis: Natasha Vidangos, Lindsey Griffith, Francisco Flores-Espino, and James McCall, "Section 3: Index of Current Status of North America Power Generation," in *Electricity in North America: Baseline and Literature Review* (Washington, DC: Department of Energy, July 2016), 21–66, https://energy.gov/epsa/downloads/electricity-north-america-baseline-and-literature-review.

7. EPSA Analysis: Natasha Vidangos, Lindsey Griffith, Francisco Flores-Espino, and James McCall, "Section 3: Index of Current Status of North America Power Generation," in *Electricity in North America: Baseline and Literature Review* (Washington, DC: Department of Energy, July 2016), 21–66, https://energy.gov/epsa/downloads/electricity-north-america-baseline-and-literature-review.

8. EPSA Analysis: Natasha Vidangos, Lindsey Griffith, Francisco Flores-Espino, and James McCall, "Section 4.6: Case Study: Minnesota Power and Manitoba Hydro: Hydro Firming of U.S. Wind Power," in *Electricity in North America: Baseline and Literature Review* (Washington, DC: Department of Energy, July 2016), 83–4, https://energy.gov/epsa/downloads/electricity-north-america-baseline-and-literature-review.

9. Owen Zinaman, Eduardo Ibanez, Donna Heimiller, Kelly Eurek, and Trieu Mai, "Findings from Scenario 2, 3, & 4," in *Modeling the Integrated Expansion of the Canadian and U.S. Power Sectors with the Regional Energy Deployment System (ReEDS)* (Golden, CO: National Renewable Energy Laboratory, July 2015), NREL/TP-6A20-63797, http://www.nrel.gov/docs/fy15osti/63797.pdf.

10. EPSA Analysis: Natasha Vidangos, Lindsey Griffith, Francisco Flores-Espino, and James McCall, "Section 5.3: The Economic Benefits of Reforms: the Mexican Industrial Sector," in *Electricity in North America: Baseline and Literature Review* (Washington, DC: Department of Energy, July 2016), 103–4, https://energy.gov/epsa/downloads/electricity-north-america-baseline-and-literature-review.

11. EPSA Analysis: Natasha Vidangos, Lindsey Griffith, Francisco Flores-Espino, and James McCall, "Section 5.5: Case Study: Export Opportunities for ERCOT," in *Electricity in North America: Baseline and Literature Review* (Washington, DC: Department of Energy, July 2016), 105–10, https://energy.gov/epsa/downloads/electricity-north-america-baseline-and-literature-review.

12. Alan J. Krupnick, Daniel Shawhan, and Kristin Hayes, *Harmonizing the Electricity Sectors Across North America: Recommendations and Action Items from Two RFF/US Department of Energy Workshops* (Washington, DC: Resources for the Future, 2016), http://www.rff.org/files/document/file/RFF-DP-16-07.pdf.

13. Canadian Electricity Association (CEA), *Canada's Electricity Industry* (Ottawa, ON: CEA, May 30, 2015), http://www.electricity.ca/media/Electricity101/Electricity101.pdf.

14. "2014 Electricity Exports and Imports Summary," Figure 2: Annual Canadian Electricity Imports (Purchases), 2005-2014, National Energy Board, last modified December 1, 2016, http://www.neb-one.gc.ca/nrg/sttstc/lctrct/stt/lctrctysmmr/2014/smmry2014-eng.html.

15. "2014 Electricity Exports and Imports Summary," Figure 3: Annual Canadian Electricity Net Exports, 2005–2014, National Energy Board, last modified December 1, 2016, http://www.neb-one.gc.ca/nrg/sttstc/lctrct/stt/lctrctysmmr/2014/smmry2014-eng.html.

16. "2015 Electricity Exports and Imports Summary," National Energy Board, last modified December 1, 2016, https://www.neb-one.gc.ca/nrg/sttstc/lctrct/stt/lctrctysmmr/2015/smmry2015-eng.html#ntbt1.

17. Nilay Manzagol and Tyler Hodge, "U.S.-Canada electricity trade increases," *Today in Energy,* Energy Information Administration, July 9, 2015, http://www.eia.gov/todayinenergy/detail.cfm?id=21992.

18. Nilay Manzagol and Tyler Hodge, "U.S.-Canada electricity trade increases," *Today in Energy,* Energy Information Administration, July 9, 2015, http://www.eia.gov/todayinenergy/detail.cfm?id=21992.

19. J. T. Miller, Jr., *Foreign Trade in Gas and Electricity In North America: A Legal and Historical Study* (New York: Praeger Publishers, 1970).

20. Pierre-Olivier Pineau, "Chapter 13: Fragmented Markets: Canadian Electricity Sectors' Underperformance," in *Evolution of Global Electricity Markets: New Paradigms, New Challenges, New Approaches,* Ed. Fereidoon P. Sioshansi (Waltham, MA: Elsevier, 2013) 363–92.

21. "Canada Facts," National Geographic, accessed July 15, 2016, http://travel.nationalgeographic.com/travel/countries/canada-facts/.

22. M. Ben Amor, P. Pineau, C. Gaudreault, and R. Samson, "Electricity Trade and GHG Emissions: Assessment of Quebec's Hydropower in the Northeastern American Market (2006–2008)," *Energy Policy* 39, no. 3 (2011): 1711–21, doi:10.1016/j.enpol.2011.01.001.

23. Alan J. Krupnick, Daniel Shawhan, and Kristin Hayes, *Harmonizing the Electricity Sectors Across North America: Recommendations and Action Items from Two RFF/US Department of Energy Workshops* (Washington, DC: Resources for the Future, 2016), http://www.rff.org/files/document/file/RFF-DP-16-07.pdf.

24. "Our History," Independent Service Operator New England, accessed July 16, 2016, http://www.iso-ne.com/about/what-we-do/history.

25. "Facts," Canadian Hydropower Association, accessed June 10, 2016, https://canadahydro.ca/facts/.

26. K. Aarons and D. Vine, *Canadian Hydropower and the Clean Power Plan* (Arlington, VA: Center for Climate and Energy Solutions, 2015), http://www.c2es.org/docUploads/canadian-hydropower-04-2015.pdf.

27. Jayant Sathaye, Oswaldo Lucon, Atiq Rahman, John Christensen, Fatima Denton, Junichi Fujino, Garvin Heath, et al., "Renewable Energy in the Context of Sustainable Energy," in *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*, edited by Ottmar Edenhofer, Ramón Pichs Madruga, Youba Sokona, Kristin Seyboth, Patrick Eickemeier, Patrick Matschoss, Gerrit Hansen, et al. (Cambridge, MA: Cambirdge University Press, 2012), http://www.ipcc.ch/report/srren/.

28. Electric Power Research Institute (EPRI), *Quantifying the Value of Hydropower in the Electric Grid: Final Report* (Washington, DC: EPRI, February 2013), 4-1, https://www1.eere.energy.gov/wind/pdfs/epri_value_hydropower_electric_grid.pdf.

29. M. Ben Amor, P. Pineau, C. Gaudreault, and R. Samson, "Electricity Trade and GHG Emissions: Assessment of Quebec's Hydropower in the Northeastern American Market (2006–2008)," *Energy Policy* 39, no. 3 (2011): 1711–21, doi:10.1016/j.enpol.2011.01.001.

30. David B. Patton, Pallas Lee VanSchaick, and Jie Chen, *2013 Assessment of the ISO New England Electricity Market* (Potomac Economics, 2014), https://iso-ne.com/static-assets/documents/markets/mktmonmit/rpts/ind_mkt_advsr/isone_2013_emm_report_final_6_25_2014.pdf.

31. Black & Veatch, *Hydro Imports Analysis* (New England States Committee on Electricity, November 2013), 1, http://nescoe.com/uploads/Hydro_Imports_Analysis_Report_01_Nov__2013_Final.pdf.

32. State House News Service, "Power industry ads knock cost, job impacts of Canadian hydropower," *New Boston Post*, April 12, 2016, http://newbostonpost.com/2016/04/12/power-industry-ads-knock-cost-job-impacts-of-canadian-hydropower/.

33. "U.S. Natural Gas Electric Power Price," Energy Information Administration, accessed July 15, 2016, http://www.eia.gov/dnav/ng/hist/n3045us3a.htm.

34. EPSA Analysis: Natasha Vidangos, Lindsey Griffith, Francisco Flores-Espino, and James McCall, "Section 4.7: Case Study: The Champlain Hudson Power Express," in *Electricity in North America: Baseline and Literature Review* (Washington, DC: Department of Energy, July 2016), 85–7, https://energy.gov/epsa/downloads/electricity-north-america-baseline-and-literature-review.

35. EPSA Analysis: Department of Energy (DOE), "Chapter IX: Siting and Permitting of TS&D Infrastructure," in *Quadrennial Energy Review: Energy Transmission, Storage, and Distribution Infrastructure* (Washington, DC: DOE, April 2015), http://energy.gov/sites/prod/files/2015/08/f25/QER%20Chapter%20IX%20Siting%20and%20Permitting%20April%202015.pdf.

36. Government Accountability Office (GAO), *National Environmental Policy Act: Little Information Exists on NEPA Analyses* (Washington, DC: GAO, April 2014), http://www.gao.gov/assets/670/662546.pdf.

37. Patricia A. Hoffman, "Energy Department Announces Approval of Great Northern Transmission Line," Department of Energy, Office of Electricity Delivery and Energy Reliability, November 16, 2016, http://energy.gov/oe/articles/energy-department-announces-approval-great-northern-transmission-line.

38. Patricia A. Hoffman, "Energy Department Announces Approval of New England Power Link," Department of Energy, Office of Electricity Delivery and Energy Reliability, December 5, 2016, http://energy.gov/oe/articles/energy-department-announces-approval-new-england-clean-power-link.

39. Joshunda Sanders, "Improving the Transmission Permitting Process to Strengthen our Nation's Grid," Department of Energy, September 21, 2016, http://energy.gov/articles/improving-transmission-permitting-process-strengthen-our-nation-s-grid.

40. Black & Veatch, *Hydro Imports Analysis* (New England States Committee on Electricity, November 2013), 2–16, http://nescoe.com/uploads/Hydro_Imports_Analysis_Report_01_Nov__2013_Final.pdf.

41. EPSA Analysis: Natasha Vidangos, Lindsey Griffith, Francisco Flores-Espino, and James McCall, "Section 3: Index of Current Status of North America Power Generation," in *Electricity in North America: Baseline and Literature Review* (Washington, DC: Department of Energy, July 2016), 21–66, https://energy.gov/epsa/downloads/electricity-north-america-baseline-and-literature-review.

42. Jordan Bakke, Zheng Zhou, and Sumeet Mudgal, *Manitoba Hydro Wind Synergy Study* (Midcontinent Independent System Operator, 2013), https://www.misoenergy.org/_layouts/MISO/ECM/Download.aspx?ID=160821.

43. Kassia Micek, "ERCOT Asks Lower Rio Grande Valley Residents to Limit Electric Usage," S&P Global Platts, June 3, 2015, http://www.platts.com/latest-news/electric-power/houston/ercot-asks-lower-rio-grande-valley-residents-21550057.

44. "Mexico Population Map," Population Labs, accessed June 21, 2016, http://www.populationlabs.com/Mexico_Population.asp.

45. "Población, Hogares, y Vivienda: Cuardo Resumen," Instituto Nacional de Estadistica y Geografia, last modified November 24, 2016, http://www3.inegi.org.mx/sistemas/temas/default.aspx?s=est&c=17484.

46. “Cooperación de América del Norte en Información Energética: Datos de Comercio al Exterior,” Comisión Reguladora de Energía–Centro Nacional de Control de Energía, accessed June 21, 2016, http://base.energia.gob.mx/nacei/comercio_exterior.aspx.

47. Clotilde Bonetto and Mark Storry, “Power in Mexico: A Brief History of Mexico’s Power Sector,” *Power Magazine*, May 1, 2010, http://www.powermag.com/power-in-mexico-a-brief-history-of-mexicos-power-sector/.

48. Raquel Bierzwinsky, David Jimenez, and Javier Felix, *Special Update: A New Power Market in Mexico* (New York: Chadbourne, September 2014), 1, http://www.chadbourne.com/sites/default/files/publications/new_power_market_mexico_0914.pdf.

49. Lisa Viscidi and Paul Shortell, *A Brighter Future for Mexico: The Promise and Challenge of Electricity Reform* (Washington, DC: Inter-American Dialogue, June 2014), 1, http://archive.thedialogue.org/uploads/IAD9603_MexicanEnergyFINAL.pdf.

50. Secretariat de Energia, Mexico.

51. Commentary from SENER, QER 1.2 Stakeholder Meeting, February 25, 2016, Mexico City, Mexico.

52. Bob Black, “U.S. Natural Gas Exports to Mexico Taking Off,” *Forbes,* August 3, 2015, http://www.forbes.com/sites/drillinginfo/2015/08/03/u-s-natural-gas-exports-to-mexico-taking-off/#441508465cd9.

53. Jorge Alvarez and Fabián Valencia, *Made in Mexico: Energy Reform and Manufacturing Growth* (Washington, DC: International Monetary Fund, February 2015), 4, https://www.imf.org/external/pubs/ft/wp/2015/wp1545.pdf.

54. Jorge Alvarez and Fabián Valencia, *Made in Mexico: Energy Reform and Manufacturing Growth* (Washington, DC: International Monetary Fund, February 2015), 4, https://www.imf.org/external/pubs/ft/wp/2015/wp1545.pdf.

55. Jorge Alvarez and Fabián Valencia, *Made in Mexico: Energy Reform and Manufacturing Growth* (Washington, DC: International Monetary Fund, February 2015), 4, https://www.imf.org/external/pubs/ft/wp/2015/wp1545.pdf.

56. Lisa Viscidi and Paul Shortell, *A Brighter Future for Mexico: The Promise and Challenge of Electricity Reform* (Washington, DC: Inter-American Dialogue, June 2014), http://archive.thedialogue.org/uploads/IAD9603_MexicanEnergyFINAL.pdf.

57. Secretaría de Energía, “Programa de Desarrollo del Sistema Eléctrico Nacional,” May 30, 2016, https://www.gob.mx/sener/acciones-y-programas/programa-de-desarrollo-del-sistema-electrico-nacional-33462?idiom=es.

58. Nilay Manzagol and Tyler Hodge, “Mexico electricity market reforms attempt to reduce costs and develop new capacity,” *Today in Energy*, Energy Information Administration, July 5, 2016, http://www.eia.gov/todayinenergy/detail.cfm?id=26932.

59. “Wholesale Electricity and Natural Gas Market Data: Current Year,” Energy Information Administration, accessed July 15, 2016, http://www.eia.gov/electricity/wholesale/.

60. Mike Ford, “Mexico’s energy ministry projects rapid near-term growth of natural gas imports from U.S.,” *Today in Energy*, Energy Information Administration, May 29, 2014, http://www.eia.gov/todayinenergy/detail.php?id=16471.

61. Secretaría de Energía, “Programa de Desarrollo del Sistema Eléctrico Nacional,” May 30, 2016, https://www.gob.mx/sener/acciones-y-programas/programa-de-desarrollo-del-sistema-electrico-nacional-33462?idiom=es.

62. Nicolas Borda and Evert Sanchez Alonso, “Mexico: Ministry of Energy Issues the PRODESEN 2016-2030,” Haynesboone, June 3, 2016, http://www.haynesboone.com/news-and-events/news/alerts/2016/06/03/mexico-ministry-of-energy-issues-the-prodesen-2016-2030.

63. Presentation by Mexico’s Secretariat of Energy, North American Energy Minister’s Meeting, Winnipeg, Manitoba, February 24, 2016.

64. Jorge Alvarez and Fabián Valencia, *Made in Mexico: Energy Reform and Manufacturing Growth* (Washington, DC: International Monetary Fund, February 2015), https://www.imf.org/external/pubs/ft/wp/2015/wp1545.pdf.

65. United Mexican States' Energy Transition Law (2015), http://www.iea.org/policiesandmeasures/pams/mexico/name-153753-en.php.

66. César Alejandro Hernández Alva, "Overview of Electricity Policy in Mexico," presentation to the Mexican Secretariat of Energy, April 2016.

67. Federal Energy Regulatory Commission, "Electric Power in the United States and Canada: Opportunities for Regulatory and Planning Harmonization," Resources for the Future/Department of Energy Workshop, Albuquerque, New Mexico, October 2015.

68. "Open Access Transmission Tariff (OATT) Reform," Federal Energy Regulatory Commission, last modified December 15 2016, http://www.ferc.gov/industries/electric/indus-act/oatt-reform.asp.

69. Michael Holder, "Reports: Mexico to launch carbon cap-and-trade market pilot," *Business Green*, August 16, 2016, http://www.businessgreen.com/bg/news/2468027/reports-mexico-to-launch-carbon-cap-and-trade-market-pilot.

70. Natalie Schacher, "Mexico announces launch of cap-and-trade pilot program," *Reuters*, August 15, 2016, http://www.reuters.com/article/us-mexico-environment-idUSKCN10R00B.

71. The White House, "Fact Sheet: Release of the Joint United States-Canada Electric Grid Security and Resilience Strategy," The White House Office of the Press Secretary, December 12, 2016, https://obamawhitehouse.archives.gov/the-press-office/2016/12/12/fact-sheet-release-joint-united-states-canada-electric-grid-security-and.

72. The White House, "Fact Sheet: Release of the Joint United States-Canada Electric Grid Security and Resilience Strategy," The White House Office of the Press Secretary, December 12, 2016, https://obamawhitehouse.archives.gov/the-press-office/2016/12/12/fact-sheet-release-joint-united-states-canada-electric-grid-security-and.

73. EPSA Analysis: Pacific Northwest National Laboratory (PNNL), *North America Modeling Compendium and Analysis* (Richland, WA: PNNL, March 2016), https://energy.gov/epsa/downloads/north-america-modeling-compendium-and-analysis.

74. Andrew Martinez, Kelly Eurek, Trieu Mai, and Andrew Perry, *Integrated Canada-U.S. Power Sector Modeling with the Regional Energy Deployment System (ReEDS)* (Golden, CO: National Renewable Energy Laboratory, February 2013), NREL/TP-6A20-56724, http://www.nrel.gov/docs/fy13osti/56724.pdf.