Mexico's New Energy Model

Mexico's Renewable Energy Future

A Working Paper

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Introduction

As the second-largest economy in Latin America with more than 40 million electricity customers, growing demand for power, and significant potential untapped renewable energy resources, Mexico is well positioned to expand its power generation from renewables. The energy reform has created many incentives to facilitate investment in renewables. However, a number of challenges remain.

Mexico has already developed substantial renewable energy capacity. Some 23 percent of its 73 gigawatts (GW) of installed capacity is renewable energy, including hydropower, wind, geothermal, biomass, and solar. This figure is close to the global average for renewable energy capacity of 24 percent, but well below the Latin American average of almost 50 percent.[1] In 2015, Mexico was among the top 10 destinations in the world for new clean energy investment, bringing in $4 billion.[2] Mexico is among the top three countries in Latin America for both wind and solar potential. As a volcanic region, it also has significant geothermal potential.

Potential renewable energy sources could be expanded to meet both existing and incremental demand for electricity. In line with the growth of Mexico's gross domestic product (GDP), its power demand is growing at about 3 percent per year—mainly from residential and industrial consumers—and the International Renewable Energy Agency (IRENA) estimates that generation capacity could almost double by 2030.[3] Heavy government subsidies, which keep tariffs below the cost of production for many households, have artificially boosted residential demand as well.

Electricity demand is poised to grow in both rural and urban areas. Mexico is a highly urbanized country; 80 percent of its citizens live in cities. Urban consumers use about 470 kilowatt-hours (kWh) of electricity, double that of their rural counterparts.[4] Yet even though Mexico's electrification rate is over 98 percent, almost three million Mexicans—

about 675,000 households, mostly in rural areas—still lack access to electricity.[5] Off-grid renewable energy sources often are the most efficient and cost-effective way to bring power to this section of the population. In urban areas, Mexico's government is also looking to expand the use of electric vehicles, including cars, buses, and motorcycles. By increasing renewable energy generation and expanding transport fueled by clean power, Mexico could lower its oil demand and transport-related greenhouse gas (GHG) emissions.

In this context of growing electricity demand, Mexico's power market has witnessed a major transformation under the energy reform, which was approved by the congress and signed into law by President Enrique Peña Nieto in December 2013 and fully implemented in 2018. The reform broke the monopoly of the vertically integrated state utility, the Comisión Federal de Electricidad (Federal Electricity Commission; CFE), and fully opened the generation market to private companies. The reform also created an independent system operator, the Centro Nacional de Control de Energía (National Center for Energy Control; CENACE), and allowed private players to acquire transmission rights. In 2015, the government published the clean energy power auction rules as part of the reform, and in 2016 the wholesale electricity market started operations.

The energy reform legislation also reiterated Mexico's aggressive target to generate 35 percent of its power from clean sources by 2024 and imposed interim targets to reach that goal. Although Mexican legislation defines "clean energy" to include renewable sources such as wind, solar, geothermal, biomass, and hydro, it also includes cleaner energy sources not generally defined as renewables, such as nuclear and efficient cogeneration. To reach the target, the reform also includes the creation of Clean Energy Certificates (CEC) setting a minimum level of electricity consumption from clean energy sources for all large consumers in Mexico, including the CFE, and allowing market participants to buy and sell these certificates in a cap-and-trade scheme.

Although this framework provides important incentives to promote clean energy, renewable energy developers still face challenges. Mexico's power grid is in poor

condition owing to years of underinvestment by CFE, and power lines throughout the country need to be upgraded and expanded. This is a particular challenge for renewable energy developers because most of the country's wind and solar resources are in remote areas far from population centers. In addition, although costs for wind and solar have declined precipitously in recent years—over the past decade, global prices for solar panels have dropped by 80 percent, thanks largely to a booming industry in China—renewables in Mexico continue to face steep competition from cheap natural gas imports from the United States. Finally, local communities have opposed developers' plans to construct renewable energy generation and transmission projects, much as other energy, transport, and extractive industries projects all over the world have faced similar local opposition.

To overcome these hurdles, Mexican policymakers should focus on three key areas. First, they should improve grid management by increasing the capacity and efficiency of the transmission and distribution system, improving demand-side management, and incentivizing distributed energy. Second, they should make renewable energy more competitive by expanding fiscal incentives for certain technologies and building up the local industry. Third, they should garner local community support for renewable energy infrastructure by improving the process for land consultation and disputes and developing community energy systems.

Regulatory Framework

The energy reform introduced two key laws— the Electricity Industry Law and the Energy Transition Law— which are encouraging investment, particularly from private companies, in the power sector, while also advancing clean energy targets. These laws are part of a broader policy framework in Mexico for promoting clean energy and climate change goals. These goals preceded the reform, and this framework continues to complement its objectives.

A Framework for Clean Energy in Mexico

Even before the energy reform was approved and implemented, Mexico had established laws and regulations that set the stage for increased generation from renewable energy sources. In 2008, the Law for the Use of Renewable Energies and Financing the Energy Transition was published in an effort to encourage the use of renewable energy and clean technologies for electricity generation and develop mechanisms to finance the energy transition. In 2012, Mexico approved one of the first pieces of comprehensive climate change legislation to guide national policy, which included a General Law on Climate Change, a Special Program on Climate Change, and a National Strategy on Climate Change.

In 2015, in the lead-up to the 21st United Nations Conference of Parties (COP21), where almost 200 countries signed on to the Paris Climate Accord, Mexico became the first developing country to submit its intended nationally determined contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC). In its INDC, which outlined the country's plans for climate action over the following five years, Mexico set an unconditional target to reduce GHG emissions by 22 percent below the baseline by 2030. The country also established a more ambitious target to reduce GHG emissions by up to 36 percent below the baseline by 2030, conditional upon a global agreement that includes an international carbon price, technical cooperation, technology transfer, and access to low-cost finance. Mexico was also one of the first countries to join the "high ambition" coalition pushing for a global goal to limit global warming to 1.5 degrees Celsius, below the 2-degree Celsius target that climate scientists widely agree is necessary to avoid dangerous climate change.

Since COP21, the Mexican government has taken steps to implement its clean energy targets for the power sector. In July 2016, Mexico, along with the United States and Canada, made a series of commitments on climate change, including pledges to achieve 50 percent clean power generation across North America by 2025 and to present "mid-century, long-term low GHG emission development strategies" to the UN climate change secretariat by the end of 2016.[6] More recently, Mexico also joined 23 other countries in

the Powering Past Coal Alliance, whose members have vowed to phase out existing coal plants and freeze any new coal plant constructions that do not use carbon capture and storage technology.

Mexico has long offered fiscal and regulatory incentives to promote renewable energy not specifically designed as part of the energy reform. Although the government has eschewed heavy reliance on renewable energy subsidies, in part to encourage the most competitive renewable sources, it does provide fiscal incentives in the form of accelerated depreciation of investments in renewable energy equipment. Under the tax code, companies investing in renewable energy generation equipment can deduct up to 100 percent of their total investment during the first taxable year.[7] The tax incentive applies to all renewable energy sources, including wind, solar, hydro, ocean energy, geothermal, and biomass and waste.[8]

Distributed generation projects also have received government encouragement. Although projects larger than 500 kW require permits from the Comisión Reguladora de Energía (Energy Regulatory Commission; CRE), smaller projects require only an interconnection contract with CFE. Through Mexico's net metering scheme, consumers with self-generation (such as solar photovoltaic [PV] rooftops) can discount the energy they generate in a billing period or sell all their electricity back to the grid.[9] Between 2014 and 2016, Mexico had more than 12,600 contracts for residential distributed generation with installed capacity of some 49,000 kW, according to CRE.[10]

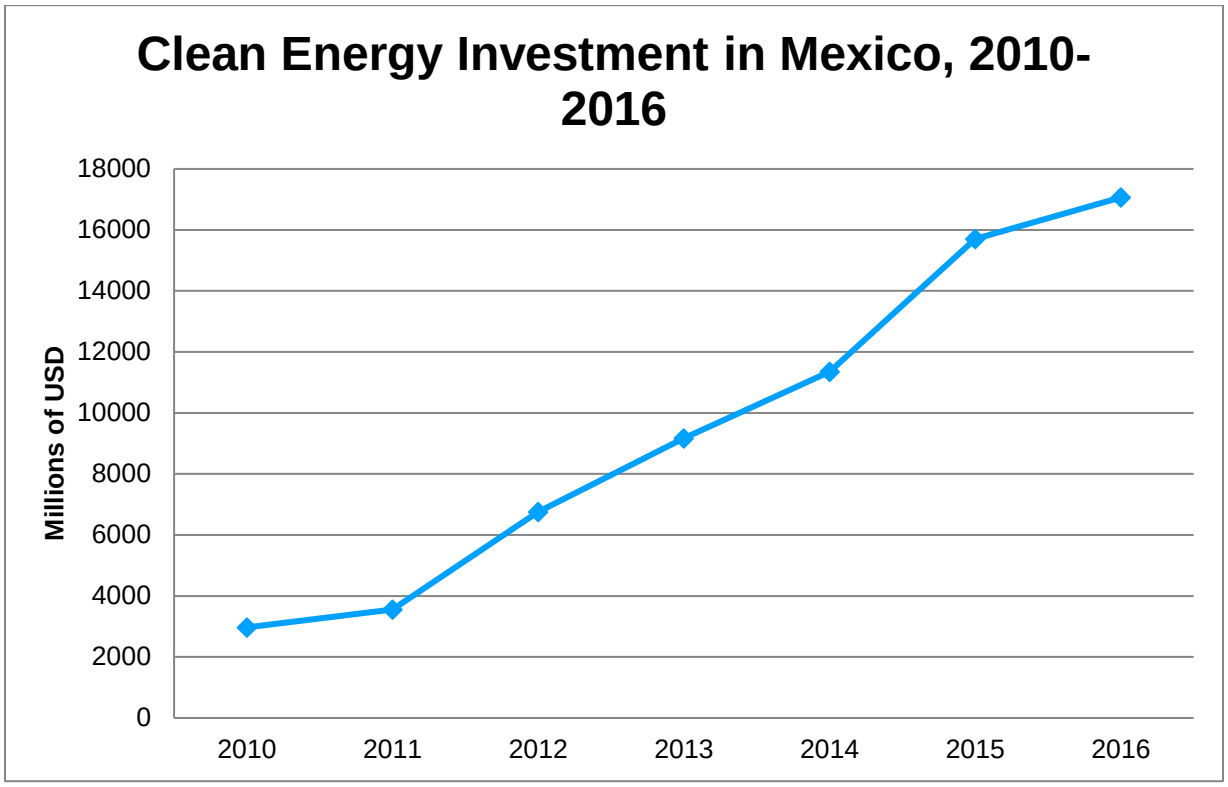
Energy Reform: The Electricity Industry and Energy Transition Laws

The energy reform created a series of laws and regulations that introduced private sector participation in the power sector in an effort to reduce generation costs, encourage investment in transmission and distribution, and accelerate the transition to clean energy. The Electricity Industry Law, established in 2014, was the key piece of legislation that set up a new regulatory framework, opening power generation to competition and creating a wholesale electricity market with private sector participation. The reform allows all participants in the newly created power market to compete under equal conditions to sell

generation supply contracts in a competitive bidding process and gives open access to the grid. The sole exception to this new open market is nuclear power generation, which remains controlled by CFE. Large-scale “qualified” users can enter the wholesale electricity market by participating in power auctions or purchasing energy directly from CFE or other suppliers at negotiated rates. At the same time, “basic” users, such as individual households, can purchase power from CFE at regulated tariffs established by CRE. The state remains responsible for planning and controlling the national power system under the newly created independent system operator CENACE, which functions as a decentralized public entity with its own personnel and assets. CENACE is responsible for managing the wholesale market, guaranteeing open access for new generators, and handling national grid planning.

Prior to the reform, private power generation was allowed only under limited schemes, such as self-generation and small independent power producers generating under 30 megawatts (MW). A lack of market competition for power generation contracts led to inefficient practices, such as the continued operation of obsolete plants. At the same time, CFE’s weak finances limited its ability to build new renewable energy generation capacity. Subsidies to residential and agricultural consumers set by the Secretaría de Hacienda y Crédito Público (Secretariat of Finance and Public Credit; SHCP) created liabilities for CFE that greatly exceeded its earnings. This widening gap—which was covered by Mexican taxpayers—caused the company’s equity to plummet by nearly 50 percent between 2007 and 2012.[11] Opening power generation to all private entities under the reform has created opportunities to attract additional investment to deploy renewable energy sources.

Figure 1. Clean Energy Investment in Mexico, 2010-2016



Source: Climatescope 2017, http://global-climatescope.org/en/country/mexico/#/financing-investments.

The Electricity Industry Law also creates incentives to improve the transmission and distribution system. CFE maintained its transmission and distribution network but the government can now contract with private firms to extend, upgrade, finance, or operate its transmission projects and modernize distribution networks. The reform also allows private generators to independently construct and operate transmission lines connected to the national grid rather than relying entirely on CFE to link to the grid. This arrangement reduces barriers to constructing new generation projects, particularly for renewable energy sources in remote locations, by attracting new technology, financing, and expertise to expand and improve the transmission and distribution networks. To facilitate this process, CRE is developing more clear, simple, and transparent transmission rates.

In addition to the rules that open power generation, transmission, and distribution to competition, one of the most important mechanisms for promoting clean energy under the new regulatory framework is the CEC system. The Electricity Industry Law established a

form of cap-and-trade system whereby qualified users and retail suppliers have clean energy quota obligations and can buy and sell CEC in the power auctions. Each 20-year CEC is equivalent to 1 megawatt-hour (MWh) of clean energy. This approach guarantees that a growing share of total demand in the power sector will be met with clean generation. Industries with consumption greater than 1 MW, including CFE, must generate at least 5 percent of their energy from renewables in 2018, with the targets increasing to 5.8 percent in 2019, 7.4 percent in 2020, 10.9 percent in 2021 and 13.9 percent in 2022. CRE is in charge of certifying the clean energy contribution, issuing certificates, and administering and monitoring the CEC scheme.

The cap–and-trade system will help Mexico to reach its goal of a 35 percent share of clean energy in power generation by 2024, which was set by another key piece of energy reform legislation, the Energy Transition Act of 2015. Although this goal mirrors the General Law of Climate Change, it also includes intermediate targets of 25 percent by 2018 and 30 percent by 2021. The power auctions and CECs are an important incentive to promote renewable energy, but the definition of “clean energy” applied to CEC as well as the national targets includes not only renewable energy but also nuclear power and efficient cogeneration.

Given Mexico’s significant potential to develop geothermal energy, the energy reform also specifically included a law on this resource. The Geothermal Energy Act regulates the survey, exploration, development, and exploitation of geothermal resources for power and heat generation. The law establishes a framework for private companies to develop these resources and facilitates the issuing of permits for site study, as well as concessions for geothermal resource exploration and development. It also differentiates geothermal water from conventional aquifers used for human consumption, allowing specialized regulation for these water sources. The Water Act was also revised to improve coordination between the Secretariat of Energy (Secretaría de Energía; SENER) and the National Water Commission (Comisión Nacional de Agua; CONAGUA).

The results of Mexico's first three power auctions indicate that the new regulatory framework already has been successful in promoting renewable energy. The auctions, in which bidders can offer packages with three products—capacity, cumulative energy, and CEC—highlighted Mexico's position as one of the countries with the lowest prices for renewable energy generation in the world. Cost per MWh dropped by more than half, from $47.78 in the first auction in 2016 to $20.15 in the third auction in 2017. The auctions drew bids from major international renewable energy players such as Italian firm Enel Green Power and US firm SunPower, as well as a number of local firms.

The first clean energy tender in early 2016 resulted in 18 contracts for 11 solar PV projects with 1,691 MW of capacity and 5 wind power projects with 394 MW of capacity, as well as five million CECs with an average price of $47.78 per MWh. The first auction was widely viewed as successful. It drew commitments for the equivalent of almost double the total solar and wind capacity that had been installed in Mexico over the previous 18 years. The projects are expected to attract more than $2 billion in investment over two years.

The second tender awarded capacity of 2,804 MW, of which 1,792 MW was solar PV and 1,012 MW was wind, as well as some nine million CECs. The auction also awarded backup power capacity contracts for solar, wind, geothermal, and combined-cycle gas turbine power. The average tender price was $33.47 per MWh. CFE was the only offtaker in the first two auctions.

The third auction resulted in 16 offers to build 2.6 MW of capacity for 15 to 20 years. Participants traded over five million CECs. Around half of the pledged investment will go to building solar plants, with the remainder in wind and natural gas. The third auction was open to private buyers, but CFE remained the largest offtaker, offering to buy 91 percent of energy and CECs in the auction. The third auction saw record low prices with an average price of $20.60 per MWh. A wind power project bid by Enel included one of the lowest electricity project prices in the world.

Table 1. 2016-2017 Auction Results Since Mexican Energy Reform

	Mar-16	Sep-16	Nov-17
Number of Pre-qualified Bidders	81	68	49
Winning Bids	18 awards to 11 companies	56 awards to 23 companies	16 awards to 11 companies
Average Price / MWh	$47.78	$33.47	$20.60
Clean Energy Certificates	5,380,911.00	9,275,534.00	5,762,647.00

Source: Comisión Reguladora de Energía, PV-Magazine, http://clusterenergetico.com/wp-content/uploads/2018/01/Certificados-Energia-Limpia-CELs.pdf

On March 15, 2018, Mexico announced the terms for its fourth long-term power auction, with results to be announced on November 2. As in the last auction, private electricity buyers will be able to participate alongside CFE. Although the energy ministry ran the first three auctions, CRE will lead this tender.

Status of Renewable Energy in Mexico

Mexico is rich in renewable energy resources with significant untapped potential. Today, large-scale hydropower is by far the leading source of renewable energy capacity, with wind a distant second. Other renewable energy sources, such as solar, geothermal, and biomass, represent only a tiny share of Mexico's electricity matrix. Although the energy reforms have opened up some new opportunities to boost investment in renewable energy, there are unique challenges to developing each of these clean energy technologies.

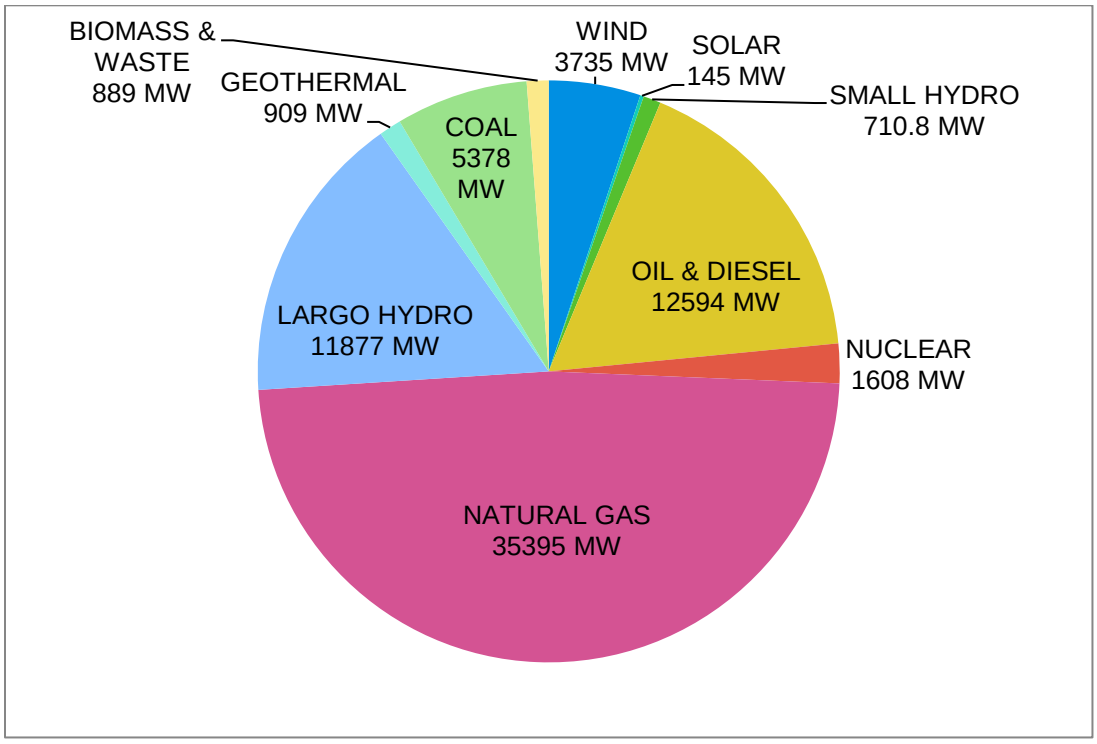
Hydropower

Large-scale hydroelectric dams are the largest source of renewable energy in Mexico, about 17 percent of installed capacity in 2016. Mexico has the capacity to roughly double its hydropower generation to 27 gigawatt-hours (GWh), taking into account both technical and economic viability.[12] Small hydropower currently represents only 1 percent of installed capacity. However, Mexico has significant potential to expand small, off-grid

hydropower projects to bring electricity to isolated communities, especially from the rivers of the Pacific Rim and in the states of Veracruz, Oaxaca, and Chiapas. Hydroelectricity in Mexico is expected to continue to grow, as a number of both large hydroelectric dams and small and micro hydro projects are planned or already under construction.

However, hydropower expansion in Mexico faces several challenges. The social and environmental costs of building new dams, including deforestation and the need to relocate entire communities, have sparked some local and regional opposition. Moreover, changing rainfall patterns and increase droughts caused by climate change could make hydroelectric power more unreliable. “Run-of-the-river” hydropower projects (which do not require large dams) and small hydropower projects can avoid these social and environmental challenges, but are more expensive ways of producing electricity. Mexico also faces challenges to developing small hydropower, such as higher costs, the lack of reliable assessments of generation potential and basic meteorological and hydrometric information, and administrative barriers to acquiring new project permits.[13] Mexico has a gross estimate of 3.2 GW in small hydropower potential, but much of the economically viable potential already has been developed or is in the pipeline.[14]

Figure 2. Installed Power Capacity by Energy Source in MW, 2016



Source: Climatescope 2017, http://global-climatescope.org/en/country/mexico/#/enabling-framework.

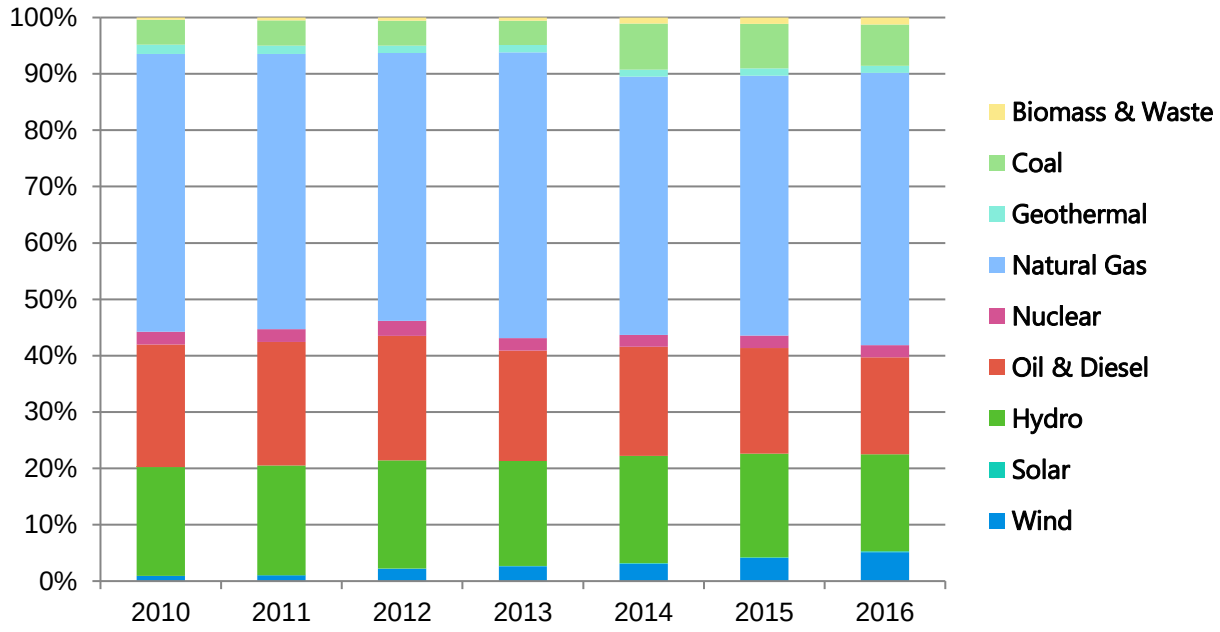
Wind

Wind power has been growing rapidly in Mexico in recent years and is currently the second-largest source of renewable energy generation, representing 5 percent of installed capacity in 2016. Mexico was one of only 25 countries worldwide with more than 1,000 MW of installed wind power in 2015, with more than 37 wind farms in states such as Oaxaca, Baja California, Chiapas, Jalisco, Tamaulipas, San Luis Potosí, and Nuevo León.[15] The country has an estimated 30 GW of wind potential,[16] and its three top regions for onshore wind potential are the Isthmus of Tehuantepec (southern Mexico) and the states of Tamaulipas (eastern Mexico) and Baja California (northwestern Mexico).

A large share of Mexico's wind generation is under self-supply schemes, as the economics are favorable for some large energy-intensive companies. Latin America's largest wind farm, the Eurus Wind Farm, located in the municipality of Zaragoza, Oaxaca, is a self-supply project for the Mexican cement giant CEMEX. Operated by ACCIONA, a US firm, the project is made up of 17 wind turbines. Its 250.5 MW capacity can cover a quarter of the total energy demand from CEMEX's cement plants.

Despite these promising developments, much of the high-quality wind potential remains untapped, owing mainly to the lack of transmission capacity. In addition, Mexico does not have a complete domestic wind supply chain, so the industry will continue to rely on imports.[17]

Figure 3. Installed Power Capacity Percentages by Energy Source, 2010-2016



Source: Climatescope 2017, http://global-climatescope.org/en/country/mexico/#/enabling-framework.

Solar

Although solar power currently represents only about 0.1 percent of Mexico's total installed capacity, the country's geographic location is ideal for exploiting solar resources. Estimates of Mexico's average solar irradiation range from about 5 to 6 kWh/m^2 per day, compared to an average annual solar radiation of only 2.7 KWh/m^2 per day in Leipzig, Germany, home to the world's largest solar plants.[18]

Although solar resources in Mexico have scarcely been exploited on a large-scale commercial level so far, the energy reforms have already brought in millions of dollars in promised investments to expand solar energy. Solar PV was the leading technology in all three of Mexico's clean energy auctions held to date. In 2017, Mexico saw a record $6.2 billion in solar energy investment, almost half of the total investment in the previous five years combined, according to Bloomberg New Energy Finance.[19]

In addition to large solar generation projects, Mexico has witnessed significant growth in small-scale self-supply or decentralized solar energy systems, also known as distributed

energy. In the early 1990s, more than 40,000 solar PV systems were installed to bring electricity to rural areas not connected to the national grid. More recently, solar PV installations have spread to urban rooftops. In 2007, the government introduced regulations allowing net metering so that residential and commercial buildings with solar rooftops could sell excess power back to the grid. By the end of 2012, some 1600 consumers were participating in this scheme, administered by the CFE.[20] Between 2015 and 2016 alone, installation of residential solar PV systems more than doubled from 118 MW to 244 MW, the largest amount of distributed generation in Latin America.[21]

Geothermal

Geothermal energy, which currently accounts for about 1 percent of installed capacity, is another renewable energy technology with significant growth potential. Mexico already has the fifth-largest installed geothermal power capacity after the United States, the Philippines, Indonesia, and New Zealand, and another 13.4 GW of potential.[22] The government has put significant funding into developing new technologies through its Geothermal Innovation Center. As a volcanic region, Mexico has significant potential for geothermal, a firm energy source that can complement intermittent sources such as wind and solar. The resource potential is spread throughout the country, but concentrated in the volcanic central, eastern, and southern regions.

The Geothermal Energy Law created new opportunities for deploying this resource by establishing a framework for private companies to explore and develop geothermal resources and drawing a distinction between geothermal and drinking water supplies. In 2015, SENER held a “round zero” for geothermal to determine which prospective sites and projects would be developed by CFE and which would be auctioned to investors in future bid rounds. Since the reforms, SENER has granted 21 exploration permits in seven states, and under the new scheme the private sector is expected to cover about 40.7 percent of electricity demand from geothermal resources by 2030, with the CFE covering 21 percent of demand, small producers 3.4 percent, and self-generation 8.4 percent.[23]

This developing potential notwithstanding, it is unclear how quickly geothermal energy use will grow in Mexico. Although new projects are planned, and the recent power auctions have awarded some new geothermal capacity, several units are also scheduled to be decommissioned, meaning that a larger number of new projects will have to be built just to reach a net increase in capacity. The high exploration costs, especially costs associated with drilling wells to assess the technical and economic potential of estimated resources, pose the greatest barrier.

Biomass

Biomass also represents about 1 percent of installed capacity in Mexico. The lion's share of biomass used for power generation is sugar cane bagasse used for self-supply in the sugar industry, followed by biogas power produced from agriculture, industry, and urban residues. Sugarcane bagasse accounted for almost 90 percent of all biomass power generation in 2013.[24] There are many incentives to produce electricity from biomass in Mexico. The sugarcane industry can sell excess electricity from biomass to the grid. In addition, many biomass projects with agro-industrial applications have obtained certified emissions reduction credits through the United Nations Clean Development Mechanism. The Bioenergy Law outlines regulations for activities related to biomass. Thanks to these incentives, SENER projects that Mexico will add 60 MW of installed biomass capacity between 2016 and 2030. However, to maximize Mexico's biomass potential, a biomass market would have to be created to connect supply and demand.

Challenges

Although the energy reform has created the framework for attracting investment to expand renewable energy generation, Mexico still faces numerous concerns, including challenges to managing and expanding the grid, price competition from fossil fuels, and local community opposition to potential new energy project sites.

Managing and Expanding the Transmission and Distribution System

To fully exploit Mexico's renewable energy potential, the country needs to vastly expand its transmission capacity. Wind and solar PV potential are concentrated mainly in the

northern and western parts of Mexico, distant from most population centers and industrial activity in the central and southern regions of the country. This distance between supply and demand is not insurmountable, but it means that careful planning will be needed to build out the necessary transmission infrastructure and design solutions to better integrate renewables with the grid.

Transmission capacity expansion and long-term planning for grid development are particularly important to integrate intermittent renewable energy sources—which are more abundant at certain times of the day or year—into the national grid. This irregularity poses a challenge for the new independent system operator CENACE. On a day–to-day basis, regulatory authorities must ensure that the system has enough available firm generation capacity to cover peak demand, while employing demand-side management to ensure grid reliability and lower costs. In long-term planning, regulators have to make complex forecasts for intermittent wind and solar generation. The Mexican government also needs to continue developing clear and adequate market operation rules and codes for grid connection and access to help encourage renewable power capacity development.

At the same time, Mexico also must account for high technical and nontechnical losses in the transmission and distribution network, a problem common to emerging markets. Technical losses are those associated with the transportation process or faults in the electricity distribution network; nontechnical losses are those resulting from illegal access, poor metering, and incorrect billing. Nearly half of Mexico's transmission lines are more than 20 years old. Technical and nontechnical losses have declined from a significant 30 percent in 2008 but are still high today at 14 percent.[25] Electricity losses in high-income Organization for Economic Cooperation and Development countries, by contrast, average between 6 and 8 percent of total electricity output.[26] The CFE has set a target to reduce losses to10 percent by 2018.

The government plans to expand transmission lines throughout the country. CFE plans to invest some $15 billion in transmission and $18 billion in distribution by 2029.[27] In 2017,

it launched a tender to build a 1,500-kilometer transmission line connecting Baja California to the national grid. This will be the first line built by a private company since the energy reform was enacted, meaning that it is a critical test of the reform and could encourage further investment if successful. It also opens up the possibility for California to import renewable energy from more distant parts of Mexico as the United States' largest economy looks to achieve its own clean energy goals. The government has also proposed a 1,260-kilometer line that will run from wind power–rich Oaxaca to more populous central Mexico.

High Costs

Competition from cheaper fossil fuels–based power, particularly natural gas, poses another challenge to the deployment of renewable energy in Mexico. Imports of natural gas from the United States have contributed significantly to Mexico's declining electricity costs. Owing to soaring output from the shale boom, the US natural gas benchmark Henry Hub has dropped from a peak of $8.85 per million British thermal units (Btu) in 2008 to just below $3.00 per million Btu in 2017. Between 2014 and 2015, Mexican electricity tariffs decreased by around 25 percent from $0.14/kWh in 2014 to $0.10/kWh in 2015.[28] Mexico's gas consumption has doubled from 4 billion cubic feet per day (Bcf/d) in 2000 to 8 Bcf/d at present, with new natural gas–fired power generation accounting for half of this growth.[29] More demand from power generation is expected over the coming years, as the CFE continues to convert fuel oil–fired power plants to cleaner and cheaper natural gas, which produces almost 30 percent less carbon dioxide than oil.[30] In addition, the energy reform has encouraged investment in new natural gas pipeline infrastructure, both within Mexico and across the border to the United States. This year, a CFE-led plan to build 22 new pipelines covering 10,000 kilometers is expected to wrap up, tripling the capacity of Mexico's pipeline network. Through October 2017, gas imports from the United States averaged 4.6 Bcf/d, up from an average of 0.9 Bcf/d in 2010, of which 91 percent came via pipeline.[31]

Although low-priced natural gas has helped to cut electricity rates for industrial users—which, unlike residential users, do not receive heavily subsidized rates—these low prices

also could be a disincentive to renewable energy production. Many renewable energy projects are not cost-competitive when compared to conventional generation technologies. Under current regulations, CENACE is required to dispatch the most cost-efficient energy, a system that has tended to favor conventional energy technologies like natural gas and coal over renewables. The new CEC scheme should in principle provide an economic signal to build more renewable energy capacity, replacing fossil fuel generation by placing a price on carbon. However, some critics believe that the scheme is not aggressive enough to move Mexico toward zero carbon energy. First, the CEC scheme places no ceiling or floor on carbon prices, so prices may be too low to act as incentives for renewable energy investment. Second, Mexico's clean energy targets and CEC-eligible projects include efficient natural gas, so there is currently no official goal to move Mexico toward zero carbon energy.

New efficient natural gas power plants will reduce emissions in the short term as oil- and coal-fired generation are transitioned to gas, but this infrastructure, which will remain in operation for decades, ultimately will increase emissions compared to building zero carbon energy infrastructure. This situation appears to reflect insufficient coordination and integration between energy and climate change planning. Natural gas, coal, and nuclear power plants all have long plant life expectancy—about 50 years—so plants that have been built since the 1980s probably will not be retired before 2030. In 2011, the average age of Mexico's coal and natural gas plants was only 17 and 13 years, respectively. The government does not have plans to retire older coal, oil, or natural gas–based infrastructure before the end of its life expectancy.

Of further concern, the prices offered in recent auctions are so low that they may not be economically feasible, and the developers will be unable to acquire financing to actually build the promised capacity. Some companies may even be hoping to renegotiate their contract later. The high number of prequalified bidders for the auction is also tied to the low requirements for prequalification. Mexico has seen some cases of projects that acquired permits for construction and generation but could not be deployed because they were not economically viable without any further subsidy or financial support. In recent

auctions, some bidders have reportedly used low-quality data and failed to perform proper assessments before submitting bids—for example, by submitting a bid for a project to be built in a protected national park. If developers face unforeseen environmental or social challenges that increase the costs of the project and alter the financial structure of the deal, they may be unable to move forward with construction.

High costs and lack of availability of local renewable energy equipment and services also could make these energy sources less competitive in Mexico. Until now, developers have had little difficulty acquiring renewable energy technology and components, most of which are imported, because the market is small. But if the industry grows rapidly, then the supply chain will likely develop bottlenecks. Massive investments would be required for Mexico to build its own complete equipment supply industry for large-scale renewable energy generation plants. Significantly increasing the use of solar panels for distributed generation in Mexico would pose another set of challenges, as homeowners and retail businesses would need access to a large domestic supply not only of equipment but also of system design and installation expertise.

Local Opposition

As in the rest of Latin America and many other countries, project developers in Mexico face major challenges in acquiring land rights and the consent of local communities to build power plants and transmission lines. The Electricity Industry Law requires the energy ministry to hold a formal consultation process with residents, including indigenous groups, before launching a project. Mexico has also required free and informed prior consultation under International Labour Organization rule 169 in its constitution since 2011, but specific procedures are lacking and implementation has been spotty.[32] Mexico also requires energy companies to pay local communities for the use of their lands, and dictates that the amount of those payments be determined through direct negotiations between the companies and residents. The law also calls for a social-impact evaluation as a precondition for approval of any new energy project.

The complex structure of land ownership in Mexico further complicates the consultation and land rights acquisition process for renewable energy projects. Roughly half of Mexico's land is privately owned, and the remaining half is collectively owned under the country's social property model in *ejidos* or other community land tenure structures. To build a renewable energy project on collectively owned lands, developers must consult not with individual property owners but with dozens or even hundreds of people who own the land—a more lengthy and expensive process that requires companies to hire local experts. In Oaxaca, where most of the country's wind farms are concentrated, more than 75 percent of the territory ownership is under the social property model.[33] Some developers have been unable to obtain land rights at all and have engaged in multiyear court battles over land rights. These legal complications also make it more difficult to attain financing.

Consulting and negotiating with indigenous communities, which make up about 13 percent of Mexico's population, present unique challenges for developers of renewable energy and other infrastructure. Many indigenous communities have particularly strong cultural connections to their land and surrounding environment and may be even more reluctant than other groups or individuals to allow large infrastructure projects to be constructed in their territory. Indigenous communities in southern Mexico have protested the construction of wind farms after information and consent on contracts, land lease agreements, and compensation were withheld. The complex negotiations with the indigenous Zapotecas in Mexico over wind farm projects in the state of Oaxaca demonstrate the pitfalls of a poorly conducted consultation process. In 2015, over 1,000 residents of Juchitán de Zaragoza, a mainly Zapotec city in Oaxaca, blocked plans to build one of Latin America's largest wind farms near the city. Community members were granted an injunction to stop Energía Eólica del Sur, an international consortium, from building a 400-MW wind farm near their homes.[34] Some residents reportedly feared that the wind farm would harm cattle, migratory birds, and bats, and did not want turbines near the city. According to the community's lawsuit, the government failed to follow the legal process for consultation by giving permits to Eólica del Sur during, rather than after, the consultation process. In January 2018, Mexico's Supreme Court ruled that the wind farm

project would have to be halted because local communities had not been appropriately consulted.[35]

The government's capacity to oversee consultations and mediate conflicts remains a question. As part of the energy reform process, SENER set up a new division that would focus on community relations, but this division's current staff and resources are not adequate to fully evaluate social impact assessments and analyze and mitigate all potential conflicts, creating a bottleneck for project developers.

Policy Recommendations

Under the current policy framework, the Mexican government has many opportunities to expand renewable energy for power generation. Policymakers should focus on three key areas:

1. Improving grid management by increasing the capacity and efficiency of the transmission and distribution system, improving demand-side management and incentivizing distributed energy.
2. Making renewable energy more cost-competitive by expanding fiscal incentives for certain clean technologies and building the local industry.
3. Garnering local community support for renewable energy infrastructure by improving the process for land consultation and disputes and developing community energy systems.

Improving Transmission and Distribution System Management

Mexico needs to increase the capacity and efficiency of the transmission and distribution system to integrate more intermittent renewable energy sources, such as wind and solar, into the grid. At the same time, the system operator CENACE needs to ensure that there is enough firm capacity for system reliability. Reliable fossil fuel sources such as natural gas likely will continue to be an important part of the electricity matrix, but renewable energy sources such as large hydropower and geothermal energy increasingly should be used to provide firm energy, particularly to replace oil- and coal-fired generation.

The energy reform created opportunities to bring in private sector investment to develop and upgrade transmission lines. The Mexican government should hold additional tenders to sell rights to build new strategic transmission lines and upgrade existing lines. The electricity regulator also should move ahead with publishing clear and transparent rates.

Mexico's government also could do more to enhance energy efficiency and demand-side management to reduce electricity demand, particularly during peak load times. Demand-side management programs should be developed in conjunction with the expansion of smart technologies, such as smart metering in residential and commercial buildings. Smart technologies can be used to send price signals to consumers to use electricity at times of the day when renewable energy sources are more abundant. Better customer management systems can reduce nontechnical losses. Under the current system, these programs would fall mainly under the purview of the CFE, as it directly supplies most customers.

If Mexico is to significantly increase its reliance on renewable energy for power generation, it will have to boost consumption not only from large-scale power projects awarded in auctions but also from small-scale distributed energy projects, which improve system reliability and reduce transmission costs. Although Mexico has allowed net metering since 2007, more progress needs to be made to introduce advanced metering infrastructure. In urban areas, smart meters should be ubiquitous in order to take advantage of opportunities to expand distributed generation on building rooftops. Incentives to build out electricity storage also would improve reliability and allow more renewables to integrate into the grid. The government should develop a specific plan for deploying smart grids and improving energy storage. Given Mexico's large geographic area, small scale off-grid renewable energy projects also will play a crucial role to ensure access to electricity in many isolated rural areas. This arrangement will help limit grid integration challenges and expand transmission capacity.

Increasing Cost-Competitiveness

Despite stiff competition from natural gas, wind and solar power projects were highly competitive in Mexico's three post-reform energy auctions. However, questions remain about the economic viability of the projects and the likelihood that they will obtain construction financing.

To avoid underbidding, the government should consistently demand financial guarantees and encourage bidders that have strong technical and financial reputations. To create more certainty for participants in the bidding process, the government should provide more information to bidders about renewable energy potential and social and environmental conditions in areas where renewable energy projects could be developed. The establishment in 2017 of the National Atlas of Zones with High Clean Energy Potential is a promising first step. The atlas is a georeferenced tool that can provide developers with access to data on wind, solar, geothermal, and biomass potential; transmission and distribution infrastructure; and any possible social or environmental challenges that could increase costs. By concentrating renewable energy projects in certain areas, fewer new power lines will be needed—a factor that also could help cut transmission costs.

To make other renewable energy sources such as geothermal and ocean energy competitive with coal and natural gas, the government likely will need to increase fiscal incentives to offset the high cost associated with these technologies. The Energy Transition Law allows SENER to propose additional tax or financial mechanisms to the finance ministry to promote energy-efficient technologies and clean distributed generation. Such incentives should remain in place for only a limited time, a transitional period that would allow companies to develop and scale up these technologies in Mexico.

The government also should start to incentivize local renewable energy industry development to improve local expertise and increase the national supply of renewable energy technology components, equipment, and services. Mexico could develop a clean energy technology cluster to bring together technology developers, entrepreneurs, and

investors. For distributed generation, Mexico needs a stronger energy service company (ESCO) market to install and maintain solar panels. Local content requirements should grow gradually over time so that the first renewable energy developers can take advantage of lower-cost equipment from other countries like China.

Garnering Local Community Support

Mexico clearly needs to improve the processes for consulting local communities and resolving land disputes over power plants and transmission lines. Experience from other Latin American countries suggests that the key to reducing conflicts is proactive and sustained government-led engagement from the start of any infrastructure project.[36] The Mexican government should develop a clear process involving various entities, including the energy ministry, energy regulators, and the CFE, to assess the social and environmental impacts of renewable energy projects and communicate this process clearly to all stakeholders. The government also will have to take a more active mediating role between companies and communities. The new SENER unit charged with managing community relations should receive more resources to mediate conflicts and draw on best practices from other countries such as Peru, Chile, and Colombia. For their part, developers should explain to communities how they can benefit from renewable energy projects, incorporate local businesses into their supply chain, and engage in dialogue early on rather than immediately trying to settle disputes in court.

Expanding “community-driven renewable energy projects,” in which communities have ownership, participation, or shared interest in projects, also can reduce the risk of local opposition. Examples of such projects in Latin America range from distributed energy projects to rural energy cooperatives, but Mexico has no large-scale, grid-connected community-driven projects. Building more small projects where communities have an equity stake and direct access to the electricity services could help to reduce local conflicts, particularly in areas like Oaxaca where communities have been strongly opposed to renewable energy projects. The Renewable Energy Policy Network for the 21st Century has proposed setting aside a specific amount of community-based electricity capacity in future auctions; adopting a national target for community-driven renewable

energy projects; and including criteria besides price in determining the winners, such as the ability to produce co-benefits like local content, jobs, and local value chains.[37]

Conclusion

Nearly six years after the energy reform was first signed into law, Mexico has a more stable and competitive framework for the electricity sector, which already has led to a huge increase in pledged investments for renewable energy generation. However, even though nonhydro renewable energy generation has grown exponentially in only a few years, the industry is still in an incipient phase. With presidential elections around the corner, Mexico may soon face significant changes in energy policy and economic policy more broadly. Although renewable energy has not been a focal point of debate in the election, as energy policy discussions have focused on the oil sector, renewables will continue to be an important issue for Mexico's economic growth and climate goals. In this context of change, it is essential that the next president maintain the positive momentum of the reform, build on the sector's successes, and work to improve policies and regulations that are still wanting. The energy reform has provided important economic signals to move Mexico toward a clean energy transition, but it is too early to tell whether renewable energy sources, especially nonhydro sources, are poised to eventually form a major share of Mexico's energy matrix. To make this potential a reality, Mexico's next government will have to maintain the key elements of the reform, keep moving ahead with the clean energy auctions, and mitigate or remove additional bottlenecks to investment.

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