
# The Yucatan Peninsula Energy Assessment: Pathways for a Clean and Sustainable Power System

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*National Renewable Energy Laboratory*

**Technical Report**
NREL/TP-7A40-79680
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# List of Acronyms

| | |
|---|---|
| 21CPP | 21st Century Power Partnership |
| CEIA | Clean Energy Investment Accelerator |
| CFE | Federal Electricity Commission |
| CRE | Energy Regulatory Commission |
| CONCANACO | Mexico's Confederation of the National Chambers of Commerce |
| CONUEE | National Commission for the Efficient Use of Energy |
| DG | distributed generation |
| ESA | Escárcega |
| FIPATERM | Fund for Energy Efficiency |
| GCR | Regional Control Area |
| GCR ORI | Orient Regional Control Center |
| GCR PEN | Peninsular Regional Control Center |
| LCOE | levelized cost of electricity |
| LMP | local marginal price |
| LNG | liquefied natural gas |
| NREL | National Renewable Energy Laboratory |
| PACC-BEA | Building Energy Efficiency Accelerator |
| PPA | power purchase agreement |
| PV | photovoltaic |
| SENER | Ministry of Energy |
| SIN | Electricity Interconnected System |
| SLC | Santa Lucía |

# Executive Summary

The Yucatan peninsula region ("Peninsula") is the Easternmost region in Mexico and comprises three states: Campeche, Yucatán, and Quintana Roo. The Peninsula has abundant natural resources, numerous archeological and protected areas, high economic growth, some of the best-known tourism in Mexico, and a unique power sector characterized by:

- **Power generation dominated by conventional fuels but rich in renewable energy potential:** Natural gas and conventional thermal plants currently provide the majority of the Peninsula's electricity. Yet, the Peninsula has excellent solar and wind technical potential. Though renewables represent only 12.5% of current generation capacity, up to 1,500 MW of new solar and wind projects are currently under development (Yucatán Energy Office).
- **Increasing electricity demand that outpaces expectations:** Between 2017–2019, the Peninsula saw steady increases in annual gross electricity consumption and peak hourly demand that outpaced government predictions. While the COVID-19 pandemic disrupted that trend in 2020, demand is expected to rebound due to increase economic expansion, reflecting the urgent need to resolve existing supply limitations (Ministry of Economy).
- **Electricity supply and reliability issues, contributing to high electricity costs:** Due to natural gas supply scarcity and insufficient transmission capacity (which creates congestion) between the Peninsula and the rest of the country, electricity is expensive and unreliable; often local generators resort to expensive, polluting alternatives (e.g., fuel oil) or to natural gas when faced with shortages (Market Monitor). As the energy needs of the Peninsula grow, there is no apparent near-term and cost-effective path to increase the supply and quality of natural gas to the levels necessary to fully satisfy the demand. Planned pipeline expansions likely will not satisfy the Peninsula's need in the short term. Imports of liquefied natural gas (LNG) can remedy shortages, but the price of LNG is significantly higher than pipeline natural gas. While transmission reinforcements and expansion are necessary for the region, operational adjustments can also provide benefits to the existing system. This confluence of challenges, means that the Yucatan faces higher electricity prices and more frequent power outages than other regions in Mexico.

In light of these challenges and opportunities, the three states of the Peninsula are developing coordinated energy plans and working together to transform their power sector by increasing the deployment of utility-scale and distributed renewable technologies, implementing energy efficiency programs, and developing sustainable transportation solutions. This report offers examples of potential actions targeted at increasing renewable energy and energy efficiency deployment in the region, including:

- Regional clean energy auctions informed by competitive renewable energy zones
- Energy efficiency programs structured for government buildings and small businesses
- Government building consumption aggregation as qualified users and design of procurement mechanisms
- Demand aggregation for distributed generation (DG) photovoltaic (PV) systems
- Use of ejidos (community agriculture) to host renewable energy deployment
- Deployment of electric vehicles to support sustainable transportation.

The implementation of some of these options is expected to make the Peninsula region more self-reliant, reduce energy prices, increase system reliability, and free natural gas supply for other uses, while attracting private sector investment and reducing electricity prices.

This report begins with an overview of the status of the power sector in Mexico's Yucatán peninsula, including key challenges, followed by policy and program solutions that pave the way for a cleaner, more sustainable power sector in the Yucatan. This work is intended to provide information to the states of the Yucatán peninsula for prioritization and future technical assistance from the 21st Century Power Partnership (21CPP) program in Mexico. The collaboration could include data gathering, capacity building, modeling and analysis, and program and policy setting to help the states and the region overall best utilize their resources to meet electricity needs, all while implementing energy efficiency measures for a more sustainable, clean, affordable, and reliable system.

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# 1 Yucatán Peninsula Power Sector Assessment

## 1.1 Power Generation and Electricity Demand

Power generation for the Peninsula primarily comprises natural gas-fueled combustion turbines and thermal power plants, with significant variation among the states. For example, the state of Quintana Roo does not have access to local sources of natural gas and relies mainly on electricity generated in the state of Yucatán (over 70% of capacity). Figure 1 and Figure 2 show the power generation capacity mix by technology and by state.

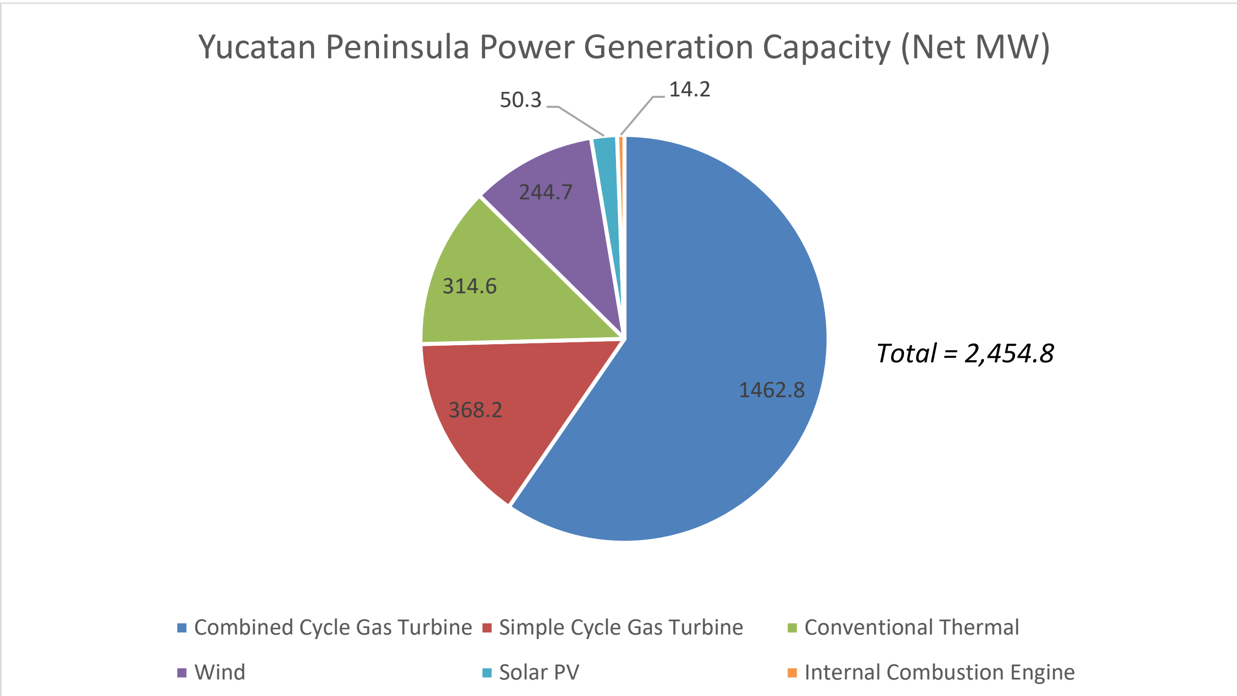


**Figure 1. Power generation capacity by technology shows 78% fossil fuels and 12% variable renewable sources**

Source: NREL with data from CENACE

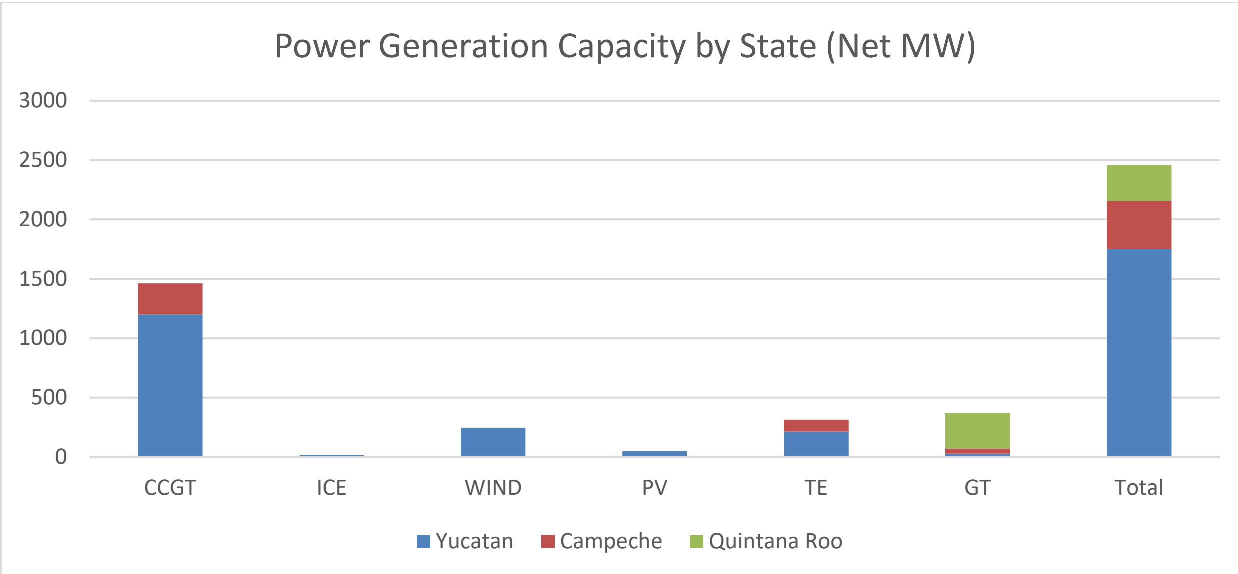


**Figure 2. State breakdown of power generation capacity by technology**

Source: NREL with data from CENACE

Mexico's interconnected power grid is divided into seven control regions operated by the national system operator, CENACE. Campeche, Yucatán, and Quintana Roo conform to the Peninsular Regional Control Center (GCR PEN, in Spanish) within Mexico's Electricity Interconnected System (SIN). The GCR PEN has suffered from electricity supply issues since 2010, mainly due to operational limitations and low supply of gas to the region (MIM 2019). Insufficient natural gas supply and its nitrogen content[1] are limiting the operational capacity of the Peninsula's generation fleet. These issues have forced some generators to convert their units to liquid fuels like diesel and fuel oil. Generators designed exclusively to operate with natural gas are left exposed to high fuel unavailability for generation.

While generation capacity appears sufficient to cover the electricity needs of the peninsula, generation and demand data show that the GCR PEN has periods of the year when the system is stressed due to the local contingencies and the available generation capacity. The 2019-2033 PRODESEN shows that electricity demand in the GCR PEN has grown steadily in recent years. In 2017, gross energy consumption and maximum demand grew by 3.04% and 3.37%, respectively, over 2016; in 2018, the same measures grew by 3.9% and 5.4%, respectively, over the previous year. According to the Market Monitor, the 2019 maximum demand reached 2,254 MW and 2,331 MW in the Day-Ahead Market and the Real-Time Market, representing a 9.4% and 13.1% growth rate over 2018, respectively. While in 2019, local capacity would appear sufficient to cover peak demand from the Day-Ahead Market and Real-Time Market, in reality, this capacity is not considered sufficient when reserve margins, dispatchable generation, and local system contingencies are considered.

According to the 2019-2033 PRODESEN planning scenarios developed by Mexico's Secretary of Energy, the average annual growth rate for electricity consumption and peak demand in the GCR PEN scenarios are 3.2% and 3.5%, respectively. Figure 3 shows the growth forecast for gross electricity

[1] PEMEX supplies natural gas to the Peninsula, and much of it contains relatively high concentrations of nitrogen gas. The nitrogen gas results from its injection into aging oil fields in attempt to increase oil output. The nitrogen content of the natural gas had been increasing every year until reaching 21% in 2019. In 2020, the average percentage of nitrogen content was 12%–16%. Since the extension of the Mayakan pipeline to a second PEMEX facility, the nitrogen content in the natural gas was reduced to around 8% (State of Yucatán Energy Office).

consumption and peak hourly demand. These predicted growth rates appear low when compared with growth rates seen from 2017–2019. In 2020, because of COVID-19, load in the GCR PEN, as in the rest of the SIN, was lower than expected and capacity was sufficient, but this will likely be a temporary effect of the pandemic. It is difficult to predict when normal load will return to the peninsula as different economic sectors are affected differently. Still, the historic trend of high demand growth raises questions about the accuracy of official planning figures by the Ministry of Energy (SENER) and reflects the urgent need for transmission investment, natural gas supply infrastructure, and higher use of alternative technologies.

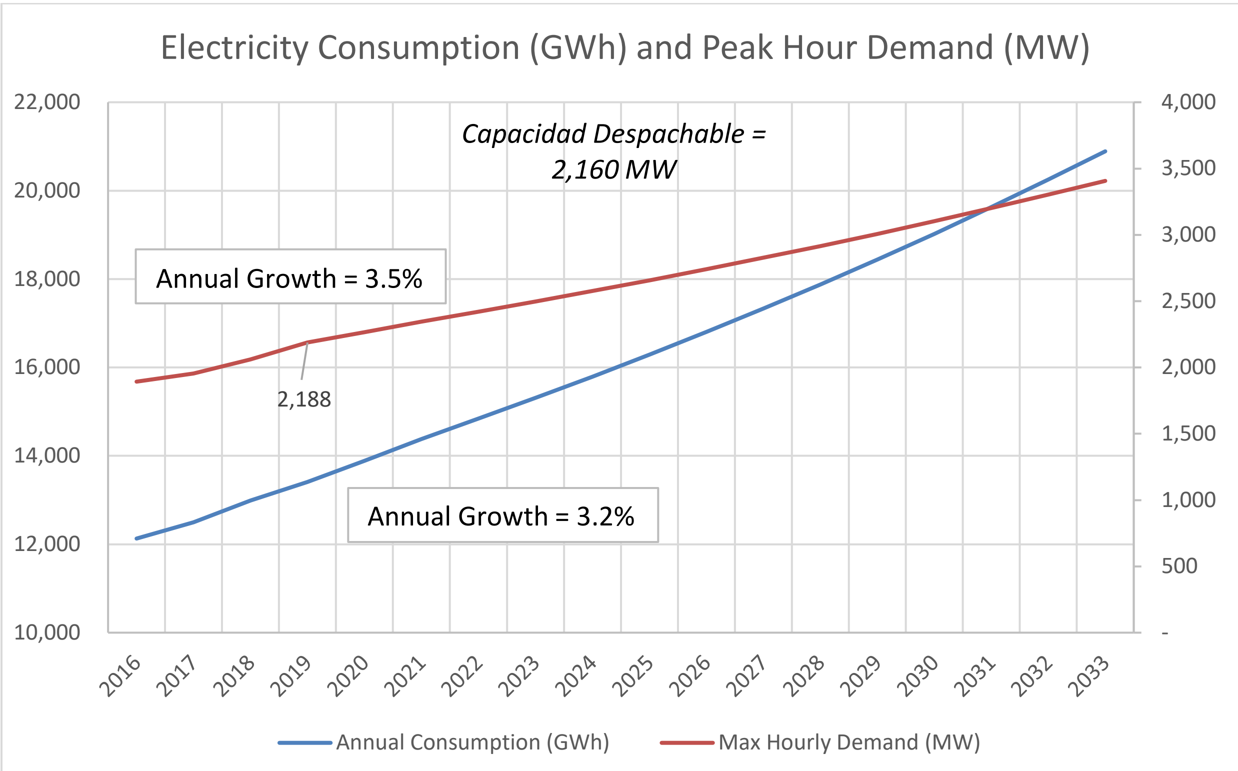


**Figure 3. Annual electricity consumption and peak demand**

Note: Right-hand axis shows max demand and left-hand axis shows annual production.

Source: NREL with data from 2019-2033 PRODESEN

To fully satisfy the current and growing demand in the Peninsula region, two new Federal Electricity Commission (CFE) plants using combined cycle gas turbine technology were announced in 2020, including: (1) a new plant in Yucatan (Merida IV) with an initial capacity of 500 MW, and (2) another plant, the first of its kind, in the state of Quintana Roo (Riviera Maya) with a capacity of 752 MW (CFE planning documents). If the two new CFE power plants are built, demand for natural gas for electricity production will increase from the current 340 MMcf/d to above 540 MMcf/d, exacerbating the problem of low supply and low quality (high nitrogen content) of gas to the region. In addition to natural gas supply uncertainties, financing availability, and environmental and social impact, studies and requirements could seriously delay the construction and operation of these two new projects.

During the last few months of 2020, it appeared that CFE was reconsidering the Riviera Maya project, and instead proposing to build the second power plant in Valladolid, Yucatán, where another plant already exists. According to CFE, transmission infrastructure is sufficient to send the new power to Quintana Roo but would likely need a series of reinforcements and investments. A study will also be necessary to understand the effects on prices and transmission congestion by moving this power plant to Valladolid. The cancellation of the Riviera Maya power plant would reverberate throughout energy and non-energy sectors in Quintana Roo. Namely, the Riviera Maya plant would have forced the extension of the Mayakan pipeline through the Cuxtal II project (See Available Gas section), which would be able to provide natural gas to the very large tourism sector and allow Quintana Roo to realize additional industrial sector opportunities.

## 1.2 Renewable Power Generation Potential

The three states of the Yucatán Peninsula are rich in renewable energy sources, particularly solar energy. Table 1 shows the technical potential[2,3] of solar and wind in the region by capacity and annual generation, taking into consideration Mexico's land exclusions and the distance to transmission that CFE, the national utility considers in their own potential calculations.

**Table 1. Wind and Solar Technical Potential (Generation and Capacity) by State**

| | | Campeche | Yucatán | Quintana Roo |
|---|---|---|---|---|
| SOLAR | Developable Area (Km2) | 20,208.39 | 21,050.56 | 4,667.50 |
| | Capacity (MW) | 727,502.05 | 757,819.99 | 168,029.83 |
| | Annual Generation (GWh) | 1,313,849.08 | 1,359,777.40 | 299,757.01 |
| WIND | Developable Area (Km2) | 533.08 | 2,041.90 | 678.46 |
| | Capacity (MW) | 1,599.26 | 6,125.71 | 2,035.42 |
| | Annual Generation (GWh) | 3,767.35 | 14,802.23 | 4,796.89 |

Source: NREL[4]

Wind and solar capacity currently account for 295 MW or 12.1% of the regional total electricity capacity. Technical potential calculated for solar and wind development in the region is 1,653,351 MW and 9,760 MW, respectively. 1,200 to 1,500 MW of new wind and solar capacity is currently at various stages of development.

As of the end of the third quarter of 2020, bulk power renewable capacity from wind and solar amounted to 295 MW or 12.1% of total capacity in the region (Yucatán Energy Office) Information from the states and from Mexico's renewable energy associations indicate that between 1,200 and 1,500 MW of new solar and wind power plants are under various stages of development (Yucatán Energy Office)

In addition to wind and solar, the Peninsula region does have other renewable resources which may offer dispatchable electricity generation including biomass, waste to energy, and other technologies. An assessment of options is provided in Appendix B.

[2] Technical potential does not account for policy and regulatory context that in turn influences economic and market potential.
[3] When evaluating wind and solar generation technical potential, it is important to understand the natural resource like wind speeds at various heights and solar irradiation, the specific technology, and type of installation chosen.
[4] Technical potential calculated using the National Renewable Energy Laboratory (NREL) Renewable Energy Data Explorer, https://www.re-explorer.org/.

## 1.3 Electricity Prices

The Yucatán Peninsula maintains some of the highest electricity prices of the National Electricity Interconnected System (SIN) in Mexico. Figure 4 shows the 2018 average local marginal prices (LMP) for each of the seven Regional Control Areas (GCR) of the SIN. The 2018 average LMP for the GCR PEN of MXP $2,292.34/MWh (well over US $ 100/MWh at 2018 exchange rates) was the highest of the system and 39% higher than its neighbor, the GCR ORI. In 2019, the average LMP for the year of all the regional control centers of the national interconnected system enjoyed reductions due to an increase in available generation from new power plants and reductions in the cost of natural gas. The control regions with the highest price reductions were the three northern regional centers of the country (between -28% and -42%), while the lowest price reduction was seen in the GCR PEN with only a -4.8% average reduction (MIM 2019).

The are several reasons for why the Yucatan faces higher electricity prices and more frequent power outages than other regions. For one, the GCR PEN has little integration with the rest of the SIN, as it has a single point of connection with the GCR ORI, which utilizes a single transmission corridor (MIM 2019). The expansion of the transmission grid has not followed the high growth of demand and supply in the region. As a result, the grid suffers from many hours of saturation that increases electricity prices. A 2019 analysis of generation costs, investment, and prices in the Mexican electricity sector, found that in general, high prices in Mexico are highly correlated to the transmission congestion in the SIN, and it is not the result of an inefficient competitive market design. (Enriquez, Rosellón et al. 2019). In addition to transmission constraints, the supply of natural gas to the peninsula is not sufficient to cover full electricity generation, causing unavailability for generation and several of the thermal plants to resort to the use of more expensive fuels such as fuel oil and diesel. Finally, solar and wind renewable technologies, which are those that provide the lowest marginal prices when the renewable resource is strongest, contribute a low percentage of the electricity generation in the area. As wind and solar power generation increase as a percentage of total generation in the peninsula, LMPs will tend lower (NREL).

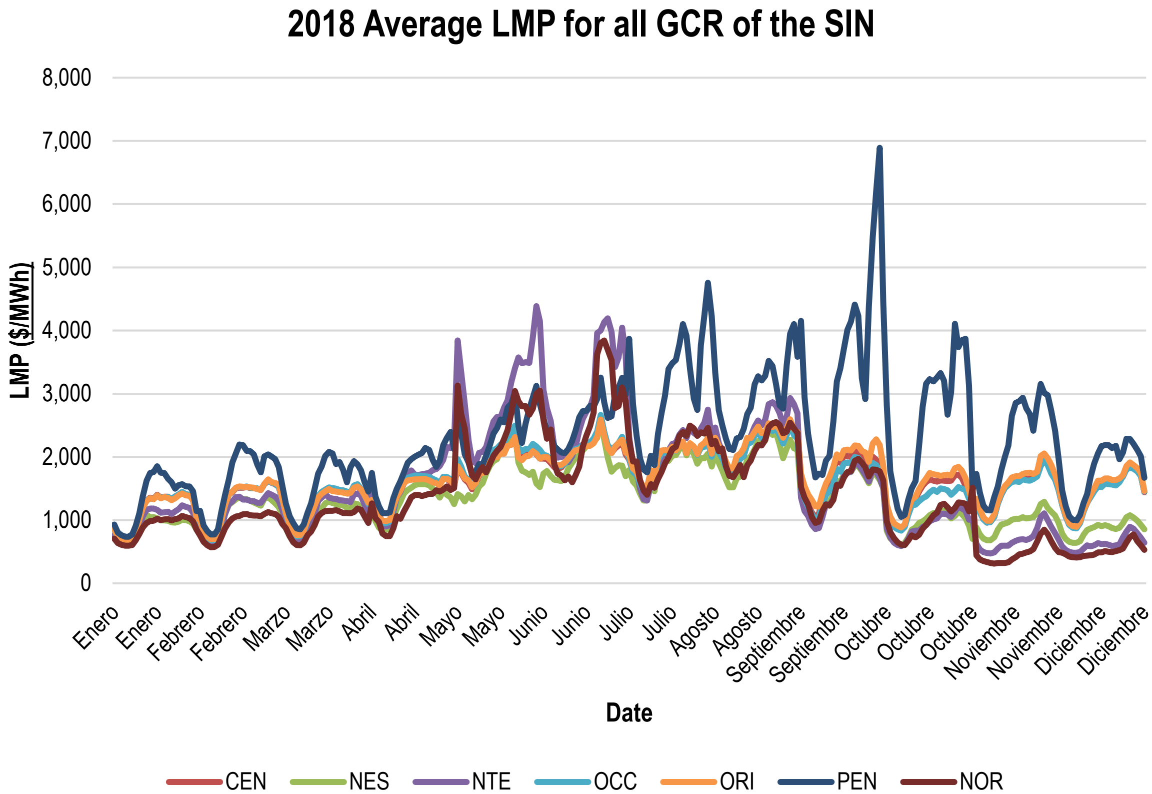


**Figure 4. 2018 local marginal electricity prices by control region**

Source: Market Monitor with data from CENACE

In 2018, average electricity prices in the peninsula were the highest of the SIN and 39% higher than its neighbor GCR ORI region. The main causes are low supply of natural gas that forces most of the primarily fossil fuel generation matrix to use fuel oil and diesel, and system unavailability, transmission congestion, and a small percentage of renewable generation

## 1.4 Available Natural Gas Supply Versus Regional Demand

Natural gas is the main fuel required for the operation of the power plants installed in this region. The scarcity of natural gas means the region faces a deficit to cover its needs for power generation and, subsequently, for industrial, commercial, and residential consumption. For this reason, it depends on electricity imports through its only transmission corridor from the GCR ORI (MIM 2019). Even with current and future planned or potential gas infrastructure projects for the region, the problem is not expected to be solved for several years.

The region suffers from a deficit in the supply of natural gas and sufficient transportation capacity to satisfy the regional needs, even if the gas was available. The CFE in the region has existing requirements of 340 MMcf/d for power generation and would require another 200 MMcf/d if its two new combined cycle power plants are built. According to CONCANACO, the demand for natural gas in the region, without the future CFE power plants, is around 500 MMcf/d, including 160 MMMcf/d from industrial and commercial requirements.

Natural gas is transported to the Peninsula through the Mayakan Energy Natural Gas Transportation System (Mayakan) owned by Engie. Figure 5 shows the Regional Control Areas in the Mexico grid and shows in the GCR PEN, the Mayakan pipeline and its two originally proposed extensions, which could fully satisfy the needs of the Peninsula. In 2020, a 16-kilometer (Cuxtal I) extension of the Mayakan pipeline was completed in 2020. With the extension, it now consists of a 796-km long telescopic-style pipeline that spans four states, starting in Tabasco and continuing through Chiapas and Campeche until reaching Valladolid in Yucatán. Mayakan does not currently reach Quintana Roo. Figure 6 shows a detailed picture of the Mayakan pipeline before the Cuxtal I extension was inaugurated in October 2020. The transportation capacity of Mayakan is 250 MMcf/d. Before the completion of the 16-km Cuxtal I extension, the available gas to the Peninsula had declined to approximately 60-80 MMcf/d of high-nitrogen (19-21%) gas. As a result of the completion of the Cuxtal I, the amount of gas transported has grown to approximately 120–140 MMcf/d, but this figure is still below 50% of the total capacity of the pipeline. The Cuxtal I project also improved the quality of the gas with the nitrogen content dropping to around 8%. Under transportation agreements, 97% or 243 MMcf/d of the capacity is contracted by CFE to deliver to the three independent electricity producers located in Campeche, in Mérida and Valladolid (Mayakan Energy). The lack of supply has forced several plants to use diesel and fuel oil.

Natural gas needs for power generation in the Peninsula are currently 340 MMcf/d, and additional demand from the industrial, commercial, and residential sectors increase that figure to 500 MMcf/d. Gas transport capacity of the Mayakan pipeline is only 250 MMcf/d, and 97% is contracted for power generation, but only 120–140 MMcf/d are available even after the Cuxtal I extension was completed, forcing many generators to convert and use fuel oil or diesel.

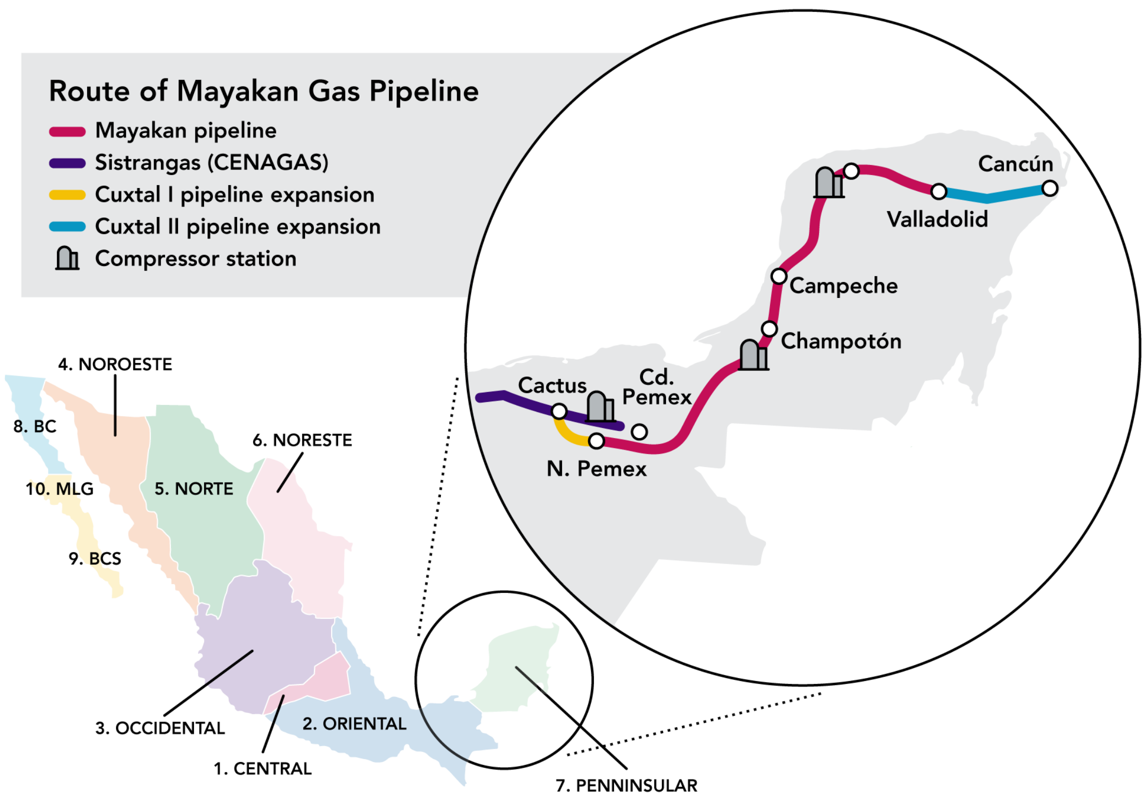


**Figure 5. Mayakan pipeline and Cuxtal expansions**

Source: NREL with information from 2019-2033 PRODESEN and Cuxtal Pipeline

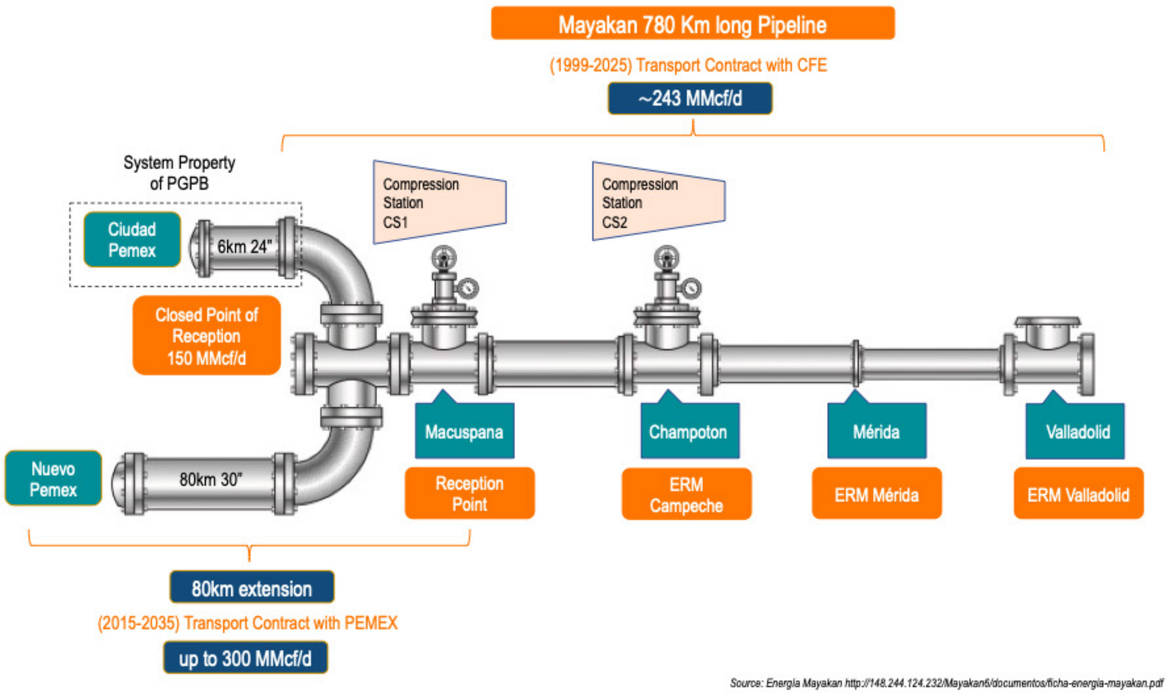


**Figure 6. Mayakan pipeline before 2020 extension was completed**

Source: Energía a debate with information from CFE.

### *1.4.1 Actions to Address Gas Fuel Constraints*

There are some actions being taken, and some planned or discussed to resolve the natural gas shortage in the GCR. The first was improving existing Mayakan infrastructure by connecting the Mayakan gas pipeline to the National Integrated Natural Gas Transportation and Storage System with the Cuxtal I extension to allow the full capacity utilization. The second Mayakan project (Cuxtal II) (not started) includes the construction of a 160-km extension from Valladolid, Yucatán, to reach Cancun, Quintana Roo (see Figure 6). The completion of Cuxtal I increased the gas in the region by allowing Mayakan to receive gas from a second PEMEX source, the CACTUS gas processing center. Cuxtal I also facilitates an eventual use of Mayakan's full supply capacity with the change of direction of the Cempoala compression station to transport natural gas to Cd. PEMEX, and by taking advantage of the entry into operation of the submarine gas pipeline between Tuxpan and South Texas. The second expansion project, Cuxtal II does not have a start date, and if CFE cancels the Riviera Maya power plant, the Cuxtal II extension may also be cancelled.

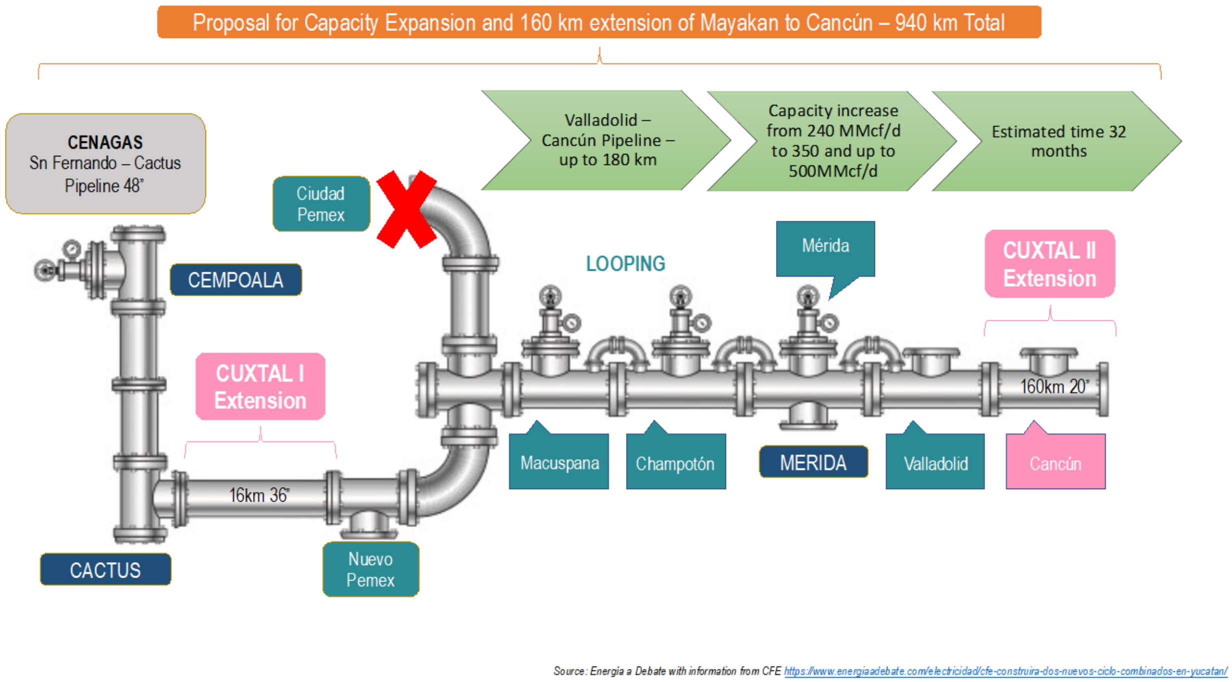


**Figure 7. Proposed infrastructure projects to the Mayakan pipeline**

Source: Energía a debate with information from CFE.

The second set of alternatives being discussed is the leasing of tankers (floating storage regasification units) for the consolidated purchase of LNG in the United States and supplying it throughout the Peninsula. States of the peninsula are analyzing and working to develop these types of alternatives. Of the projects being considered, the one that is further along is a Campeche project called MEXITERM Gas Supply. The MEXITERM project proposes to acquire and transport LNG by vessel to the Campeche coast, which would be received by a floating storage regasification unit located approximately 20 to 30 kilometers from the Campeche coast. If built, the project would start with a regasification of 175 MMcf/d that would be sent through a 20–30-kilometer offshore pipeline to Campeche, where the gas could enter the Mayakan pipeline and/or could be distributed through the use of trucks on land (Ministry for Sustainable Energy Development of the State of Campeche). If built, gas prices from this project will be higher than natural gas transported through the Mayakan pipeline.

To date, the Cuxtal I project has been completed but will not solve the problem of gas supply to the region. Thus, until some remedial action is taken, the prospect of natural gas shortages and sparseness of GCR PEN generation capacity will exist.

## 1.5 Regional Interconnection and Opportunities for Grid Expansion

As mentioned before, the GCR PEN is interconnected with the GCR ORI, and the interconnection suffers from saturation practically every month of the year. During the months of higher temperatures when electricity demand increases throughout the region, the number of saturation hours increases considerably. Figure 8 shows the current transmission infrastructure of the GCR PEN and the interconnection with the GCR ORI. The two regions are interconnected through one corridor with four transmission lines: (i) two at 230 kV, the first between the Macuspana II and Santa Lucía (SLC) substations, and the second between the Los Ríos and SLC substations; and (ii) two 400-kV lines, both between the Tabasco Power and Escárcega (ESA) substations. In the Chetumal Cargo Area, the GCR PEN is interconnected with the

Belize electrical system through a simple 115 kV circuit, which is used for export operations. (Independent Market Monitor 2019 report [MIM 2019]).

Transmission between the ORI and PEN GCRs is normally limited by a link or gate within the GCR PEN, defined by the interconnection between the SLC and ESA substations and between the Tabasco Power station and ESA substations, as described above. Figure 9 shows the transmission system of the GCR PEN and the entrance gate to the ESA substation, which has come to limit the flows between the GCR ORI and PEN. The peninsular region suffers from reliability of supply in times of high demand and due to the stress in the system. As an example, there are transmission lines in certain areas, including two 400-kV lines between ESA and Ticul II that share transmission towers, which makes them vulnerable to possible double contingencies when their physical structure is at risk. This was the case on April 5 and 22, 2019, when fires on sugar fields below the towers impacted the lines and caused power outages. During these double contingencies, the system would try to redirect power to the 230 kV lines. On the first event on April 5, the event occurred at a time of high demand for electricity, and most of the GCR PEN went offline for almost 3 hours. During the second event on April 22, the operating conditions were different, and the 230-kV lines were able to better react to the event. The loss of power during this time lasted just 17 minutes (MIM 2019).

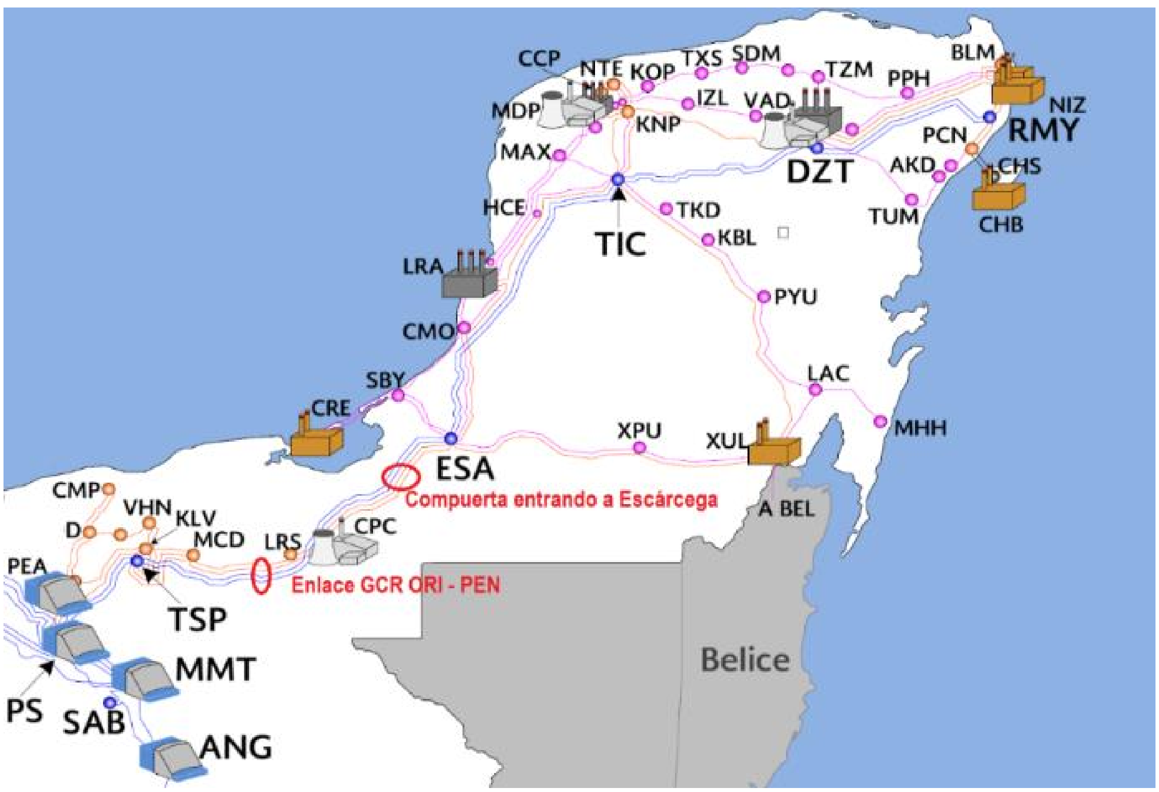


**Figure 8. GCR PEN transmission and interconnection with the GCR ORI**

Note: For the purposes of this graph, it is considered that the electrical substation SLC and the generator CPC are geographically at the same point

Source: MIM 2019

While transmission reinforcement and expansion are necessary for the region, especially with the building of two new CFE power plants and other renewable projects, operational adjustments can also provide benefits to the existing system. As an example of these, the MIM 2019 annual report indicates that between April and July 2018, the saturation of the connection between the two GCRs was 150 hours per month on average. During the same period of 2019, the saturation increased by 65%, reaching an average of 248 hours per month. In August 2019, CENACE implemented remedial action changes, and for the months of August and September, the saturation was reduced to 88 hours, compared to 366 hours during the same two months in 2018.

# 2 Pathways for the Transformation of the Power Sector in the Yucatan Peninsula

In this section[5], we discuss a series of policy options for the states in the peninsula to implement individually and/or regionally to increase power sector sustainability and resiliency while lowering energy prices. The state of Quintana Roo is particularly vulnerable—most of its power is imported from Yucatan. The announcement of the Riviera Maya power plant was expected to bring some much-needed relief through local generation and the possibility of finally having natural gas available through the Mayakan pipeline. If CFE officially decides to build the second plant in Yucatan, Quintana Roo may need to work toward the deployment of large amounts of renewable power across the state. This section is divided into renewable energy opportunities for bulk power, distributed generation (DG), and energy efficiency. The Yucatan Peninsula possesses strong solar and wind resources and already has demonstrated feasibility with multiple projects. However, the Peninsula also has other resources that should be explored for sustainable and renewable energy production. The extensive agricultural economy may offer opportunities for bioenergy production (biomass and biogas). Trash and wastewater may also be turned into useful energy. Other technologies are worth exploring, such as ocean and hydropower. Finally, the Peninsula may also look to importing sustainable and renewable solutions where Peninsular production is not readily supported.

## 2.1 Bulk Power Renewable Energy Opportunities

There are several opportunities for the states to promote continued deployment of utility-scale renewable energy generation (for Mexico, this is capacity above 500 kW, while in many countries “utility-scale” typically refers to projects with greater than several MW generating capacity). The options discussed here include: the design of regional auctions, actions to promote development of single power purchase agreement (PPA) projects, and solutions for aggregated procurement programs. We also discuss a new opportunity in Mexico to develop solar ejidos. This last opportunity may work for bulk power and for DG projects, depending on the situation. There are other large-scale renewable power options that are not discussed here, including developers who decide to build new power plants and participate as merchant sellers into the wholesale market due to the historically high LMP in the region.

One key barrier that these opportunities face is the physical limitations of the current grid infrastructure and the congestion problems in the region. A sustainable grid requires reinforcements, expansion of existing lines, and the building of additional lines to reach and connect the best renewable resources with the load centers.

In 2018, the SENER requested NREL to analyze Competitive Renewable Energy Zones in Mexico (see Figure 9) where new substations would be built to expand the transmission system to best meet current and future grid demands and for design of future long-term clean energy auctions. The results of the analysis included two zones chosen for transmission expansion in the Peninsular Region, one in Campeche and one in Yucatán.

Under a transparent process with participation of the state governments and the private sector, and in coordination with the local CENACE, the states could develop or commission a regional version of the Mexico Competitive Renewable Energy Zone study to determine the best areas for regional auctions and single PPA renewable projects. The study could analyze the current transmission grid and necessary

[5] This section does not cover all of the previous potential solutions – it only covers renewable and energy efficiency options. Thus, actions being taken in natural gas markets, grid expansion opportunities, are not expanded on here.

reinforcements. The study could provide a list of suitable areas that states could help pre-approve in terms of environmental and social requirements, and with the input from the system operator certain areas would be prioritized to improve the reliability of the system.

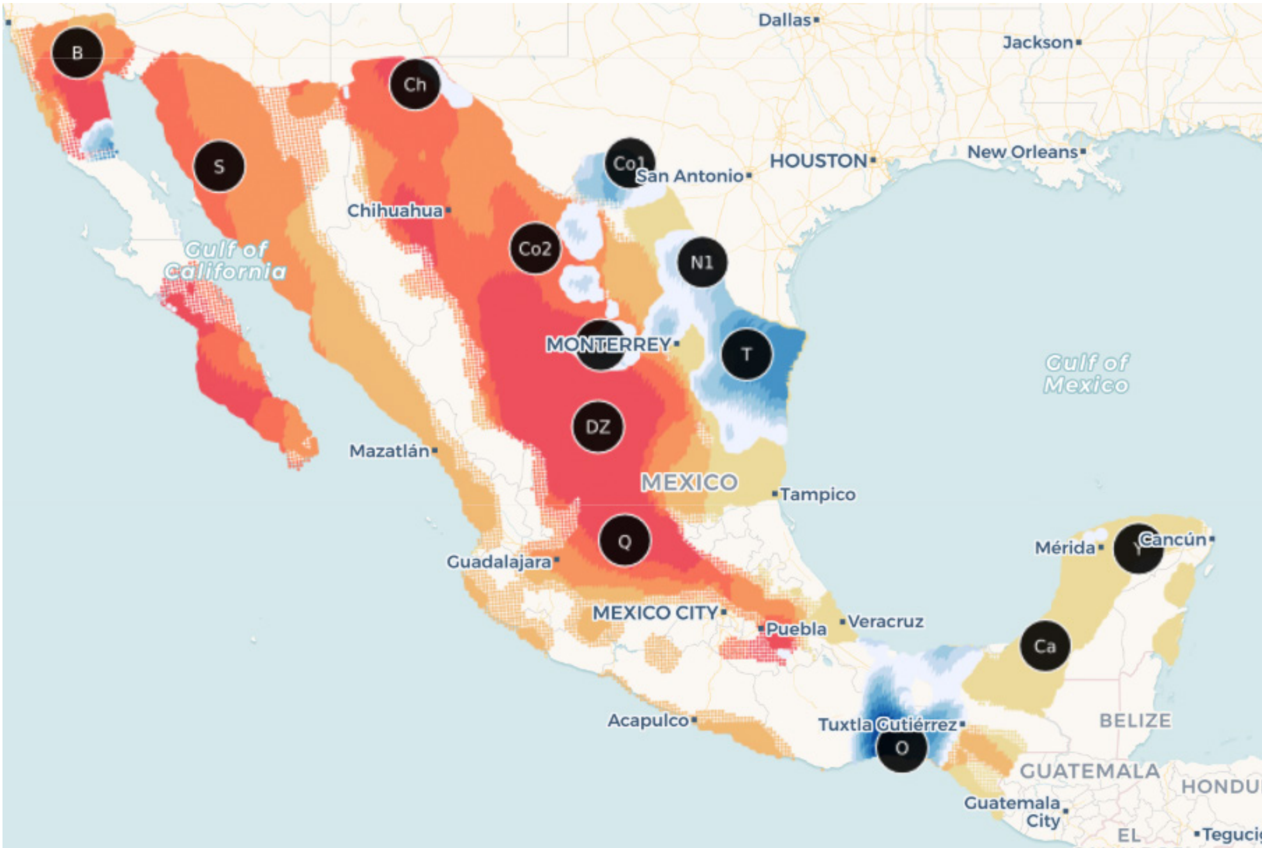


**Figure 9. Results of the Mexico Renewable Energy Zone analysis**

Note: Yellow, orange and red show level of solar irradiation resource, and shades of blue represents level of wind resource. Darker color represents higher resource. Source: NREL

States can utilize local knowledge and together with NREL's resource data, technical capabilities and modelling expertise, fast track interconnection friendly areas to develop a series of bulk power renewable energy programs in the Peninsula region.

### *2.1.1 Regional Clean Energy Auctions*

The increasing popularity of renewable energy auctions (also sometimes called "reverse auctions") around the world is due to their effectiveness as a market-led approach that can attract large amounts of investment for multiple projects at low prices and without providing expensive subsidies (IDB 2019). Auction design has many characteristics that can be modified to meet the needs of a country or region, including technology type, geographic location, and required services with specific conditions. A quantity-based type of auction strategy is perhaps the most popular. The auctioned volume can be determined based on the maximum capacity that the existing system can accommodate. Zone-specific capacity limits based on transmission constraints have been implemented in many auctions, including in Germany, Mexico, and Peru. Zone-specific capacity limits can even be set for each technology, as in Kazakhstan, where solar and wind are distributed among regions (IRENA 2019).

In Mexico, long-term auctions were created as the driving mechanism of the Electricity Industry Law to allow the basic service provider (CFE basic service) to enter into long-term contracts, using a competitive mechanism to meet its future needs for capacity, electric power, and clean energy certificates. Auctions in Mexico were created also to eventually allow private sector entities responsible for load to participate in this process, once a clearinghouse (Cámara de Compensación) was established. The clearinghouse would be the independent entity that could act as counterparty between sellers and buyers in the long-term auctions, assessing the financial credibility of the market participants and distributing the risk of default. For private sector buyers, the clearinghouse could ensure a stable source of payments important for supporting the financing required to develop the new power plants. The validity period of the contracts derived from the long-term auctions were 15 years for electric power and capacity and 20 years for clean energy certificates (CENACE).

One mechanism to direct projects to areas of need, primarily with transmission congestion, was the introduction of nodal price adjustments. A nodal price adjustment mechanism helps incentivize project development where generation is most needed (e.g., the Peninsular states). According to BloombergNEF, "regional nodal differences played an important role in the decision of winning bids" in the first auction leading to nearly 1 GW of projects in Yucatan state (Alves 2016a). Regional nodal differences played less of a role in the third auction because the first two auctions helped correct regional supply-demand imbalances (Demoro 2017; del Rio 2019). Mexico's first and second clean energy auctions were restricted to CFE basic service as the exclusive off-taker, while the third was open to private offtakers.

Historically, qualified users have faced a lengthy, costly, and unstandardized bilateral negotiation and contract processes with generators if they wanted to pursue clean energy—a phenomenon that the privately led clean energy auction was designed to address. According to Bravos Energy, generator and off taker interest was high for a first national private auction, which entered its final phase in March 2020 when COVID-19 hit Mexico.

Rich renewable energy resources in the Peninsular states and demonstrated private sector interest in developing those resources per the first energy auction indicate that future private and/or public-led energy auctions may deliver additional low-cost clean energy to the region. State governments can play a significant role in the deployment of state and/or regional auctions by first registering as a qualified user and together with private sector becoming the purchasers in the auction. Second, states can aid by securing land and helping to pre-approve the areas based on environmental and social requirements. States can also work with technical experts, nongovernmental organizations, and financiers to help develop the necessary market and financing mechanisms. Nonetheless, challenges to a regional private sector-led auction approach remain, including (Villarreal and Pavlovic 2020):

1. In transmission-constrained regions like the Peninsular states, additional large renewable generation developed through auctions would likely also require transmission investment. CFE and CENACE are involved in transmission system decision-making; without their cooperation, even private-sector transmission investment faces barriers. An alternative would be to design a limited auction for regions that do not require transmission investment, which could preclude the Peninsular region entirely. Also, states may be able to facilitate the use of state land that is in good interconnection zones to facilitate the process and reduce their energy contracts.
2. While state governments could be potential facilitators of clean energy auctions, the governments themselves are seen as risky off takers given their historical and fluctuating credit worthiness.
3. CENACE and SENER's recent policies (noted previously) add significant uncertainty to the renewable energy sector in Mexico, which potential participants will have to consider in their contracts. Many may not participate because of this barrier.

4. Suppressed electricity demand due to COVID-19 has led to lower energy prices, making it harder for renewables to compete, at least in the near term. In the Peninsular region, where natural gas supply is low and economic growth continues, it may be less of a factor.
5. Renewable energy auctions are more valuable to all parties when the volume of generators and offtakers is large because of inherent transaction complexity and cost. Smaller regional auctions may not have sufficient volume to justify these costs.
6. For multiple generators and offtakers in a clean energy auction, it is necessary to have a clearing house mechanism to reduce risks and provide the guarantees required by all parties in the contract.

> The Mexican energy reform through the Electricity Law allows for state and/or regional energy auctions. While these type of auctions have not yet been created, there is great interest from public and private actors. To be successful careful design and implementation with input from local governments, private sector, indigenous communities, federal agencies, and financial and energy experts.

### 2.1.2 Single PPA for Qualified Users

While the courts have sided with developers and have halted the CENACE and SENER decrees,[6] private sector developers and industrial offtakers are returning to the model of a simple PPA with one generator and one offtaker. For these options to work, users need to be generally very large energy consumers. This solution could also be used by states that register as qualified users.[7] One issue with this solution is the requirement of time, knowledge, and resources to best understand and secure the optimal choice at the best price, which may deter possible interested consumers. Smaller size consumers that cannot register as qualified users must look for other alternatives. As mentioned in the Auctions section, states could leverage deployment of renewables by helping localize optimal areas for development by working on pre-approval of these areas and ultimately as an offtaker for specific projects.

### 2.1.3 Aggregated Procurement

Smaller customers not eligible for simple PPAs could turn to aggregated procurement. In an aggregated procurement model, consumers can combine power needs to qualify for options and prices that otherwise would not be available to them. Typically, businesses consider aggregation to secure competitive electricity prices, gain access to renewable energy options, and receive guidance on available purchase options. States in Mexico can help coordinate with the business community to develop and offer aggregated procurement options. Depending on the installed capacity of the renewable systems, these would qualify as bulk power utility scale or DG.

One type of aggregated procurement that has been developed in Mexico is the Clean Energy Investment Accelerator (CEIA).[8] This program has worked closely with the Mexican Association of Industrial Parks (Asociación Mexicana de Parques Industriales) to develop a process for launching a Request for Proposals for the installation of DG PV powering multiple separate tenant companies. Doing so takes

[6] On February 3, 2021, Mexico's Supreme Court decided against SENER's Policy for Reliability, Safety, Continuity and Quality of the National Electric System. The decision in favor of the Federal Antitrust Commission claimed that SENER overstepped its authority and undermined competition by unduly strengthening the government-owned national utility (CFE) (Berrera 2021).

[7] Qualified users are end users of electricity that demand at least 1 MW.

[8] The CEIA is a nonprofit, three-way consortium comprising NREL, World Resources Institute, and Allotrope Partners to catalyzing the private sector procurement of renewable energy (both DG and bulk power renewables) in multiple countries, including Mexico.

advantage of economies of scale to enable a much lower bid price than would otherwise be submitted. This, in turn, facilitates easier acquisition of project financing. Additionally, CEIA serves as a trusted agent by both customer and developers, such that the customers—who likely know very little about the solar sector—can feel confident they will not be preyed upon by unscrupulous actors and that they are receiving a fair proposal.

The CEIA model could be used as the basis for creating aggregated procurement models with the type of characteristics found from the commercial and industrial sectors in the states of the Yucatan peninsula. Campeche, Yucatán, and Quintana Roo can fill many roles to foster accelerated large-scale renewable development. State governments and some municipalities could register as qualified users. States could educate the public, create fiscal and other incentives, and work with industrial and commercial association and the national utility to find optimal solutions.

### 2.1.4 Solar Ejidos

An ejido or "propiedad communal" is an area of communal land mainly used for agriculture, on which community members farm designated plots and collectively maintain communal holdings. While this was the original intention and was once an accurate description of ejido activity, today many ejido properties in Mexico are abandoned, with no farming or other economic activity taking place. The ejidos could benefit from hosting on-site renewable energy projects.

Throughout Mexico, there are ejidos that could benefit their communities by allowing the use of some of their land for renewable energy projects, in particular solar projects. The solar ejidos could provide the ejido owners (ejidatarios) with new or additional income options where their land is no longer usable (i.e., abandoned stone and gravel mining, areas without water access, and potential agrivoltaic sites, among others) or provide additional diversified and stable income to agricultural and livestock ejidatarios without disturbing those operations. These projects would be designed in a similar way as a single PPA project. State governments can again play many roles in promoting this solution. For example, states or municipalities could become the purchasers of the electricity produced by the ejido. States could also assist with education of ejidatarios and as promoters with financial institutions and helping design programs and processes to facilitate investment. Depending on the size of the systems installed in the ejidos, these would qualify as either DG or bulk power systems.

## 2.2 DG

DG can provide economic benefits to many residential and nonresidential consumers in the Peninsula by lowering their energy costs. DG is defined in Mexican law as generators of less than 500 kW connected to the distribution grid. As of June 2020, PV represented 99.28% of all DG contracts in Mexico (RIC Energy 2021).

Due to high electricity prices, the Peninsula has seen a significant number of PV systems installed in the past few years, with over 10,600 (Table 2) coming online as of June 2020. Merida, the capital of the state of Yucatan, accounts for more than 50 % of all DG PV systems in the Peninsula (CFE). Yucatan has a population larger than the other two states in the Peninsula as well as a higher number of DG PV systems per capita. Yucatan has 3.8 times as many PV systems per capita as Campeche and 2.6 times as many as Quintana Roo.

**Table 2. Distributed Solar Generation Installed (2017–June 2020)**

| State | Total PV Systems Installed | Total Capacity Installed (MW) | Average PV System Size (kW) |
|---|---|---|---|
| Campeche | 871 | 6.28 | 7.2 |
| Quintana Roo | 2,220 | 11.82 | 5.3 |
| Yucatan | 7,513 | 50.54 | 6.7 |
| Total | 10,604 | 68.64 | 6.5 |

Source: CRE

Mérida, Yucatan, is the only jurisdiction in the Peninsula that offers incentives for DG PV systems. Businesses that install a qualifying PV system can get a 5% to 15% discount on their property taxes. The Mérida government estimates that annual installations have increased 20% since the institution of the incentive (Diario de Yucatán 2019).

As an example of the DG business opportunities arising in the Peninsula to take advantage of the high energy prices and good solar resources, a new program called BANVERDE was launched in the state of Quintana Roo in 2020. This program provides up to 100% financing of DG PV systems for nonresidential consumers, as their electricity rates are not subsidized. The program is financed by a U.S.-based private investment group (WRB Enterprises), which has launched similar programs in several other Mexican states. In Quintana Roo, the program includes USD $15 million capital to provide partial or total financing of the DG PV systems. The nonresidential consumer signs a PPA with BANVERDE that provides a discount electricity rate over the CFE tariff. The customer becomes the full owner of the system at the end of the contract, and in the case of Quintana Roo, BANVERDE is offering full payment relief for electricity consumption for the first 6 months as an additional incentive (Estado de Yucatán 2021).

This section highlights existing and potential DG programs and policies for residential, commercial, and industrial customers in the Peninsula.

### 2.2.1 Residential Distributed Solar

According to Iniciativa Climática de México, 98.75% of residential electricity tariffs in Mexico are subsidized, and the utility customer class known as high-consumption customers (also known as DAC customers for its Spanish acronym), who comprise the other 1.25% of residential customers, do not receive a subsidy. High-consumption customers, together with commercial and industrial customers, contribute 18% of the subsidy for residential consumers; the rest is paid by the government. Mexico's electricity subsidy in 2019 was 52,000 million pesos, and the federal government budgeted 70,000 million pesos, or a 31% increase, for 2020 (Baz et al. 2015).[9] The levelized cost of electricity (LCOE) for a 10-kW system anywhere in the Peninsula is at least 34% lower than the high-consumption tariff (depending on the location, the percentage can be higher) (CFE). The data also shows that the LCOE in all three states, is approximately equal to CFE's subsidized residential rates.

Utility customers in the high-consumption tariff have the highest PV adoption rate of all residential customers, but they are only a small percentage of total customers. A combination of lower PV prices, government targeted programs, and incentives could significantly accelerate the adoption of DG PV for residential consumers in Mexico.

[9] Federal government budgets 70,000 million pesos for electricity subsidy in 2020 (Solís 2019).

#### 2.2.1.1 Hogares Solares

Hogares Solares (Solar Homes) is a business model and financing mechanism proposed by the local environmental nonprofit, Iniciativa Climática de México, to repurpose government electricity subsidies into incentives for residential customers to adopt PV systems. The long-term goal is to reduce the ongoing subsidies that the federal government pays without increasing customer tariffs. Under the program, a percentage of the current subsidies would be diverted to reduce the cost of rooftop PV systems for customers that opt into the program. The subsidy for those customers adopting PV would be reduced, but their electricity bills would not increase significantly because of the reduction in energy consumption from the grid that solar energy would provide.

Currently, CFE's Fund for Energy Efficiency (FIPATERM) program is analyzing the possibility of funding pilot projects in a few cities in the North of Mexico. The pilot projects would serve to help consumers better understand the economic benefits, including the reduction of the subsidy, and potential technical challenges of a bigger rollout, including DG integration in CFE's distributed system. States in the Yucatan peninsula that are interested in analyzing the Hogares Solares program may request technical assistance from Iniciativa Climática de México and its partners to engage FIPATERM and other funding sources.

### 2.2.2 DG for MiPyMEs

In contrast to the small percentage of residential customers that pay the highest electricity rates for their customer class, more than 87% of micro, small, and medium-size businesses (MiPyMEs) (INEEL and ICM 2019) (173,341 commercial customers across all three states) paid the highest business tariff rate in 2018 for their customer class (CFE). Additionally, commercial customer tariffs receive no subsidy. The rate paid by MiPyMEs is USD $0.16 per kWh and is at least 22% higher than the LCOE of a small-scale PV system.[10] If all the MiPyMEs converted to DG PV, collectively they could save between USD $27 million and USD $43 million every year (NREL calculation).

For businesses installing larger systems, the difference between LCOE and their current tariffs is even greater due to economies of scale. According to state officials, PV developers in the Peninsula have built DG PV systems this size and larger for as little as USD $1.10 per watt. Assuming a conservative price of $1.25 per watt, the LCOE of a 50-kW system is at least 35% lower than the electricity rate for a MiPyME.

States in the peninsula can work with solar developers, consumers, and financiers to develop policies and programs to promote these DG PV installations and help reduce the energy burden on a critical sector of the local economies.

### 2.2.3 Community Solar

Community solar, also known as shared solar or solar gardens, is a distributed solar energy deployment model that allows customers—including individual household customers, businesses, and nonprofits—to buy or lease part of a larger off-site shared solar PV system and offset their energy consumption by the energy produced by their share of the community solar system. Community solar programs allow multiple customers or "subscribers" to purchase the output from a single solar PV array. Community solar serves residential and commercial consumers that would not have the necessary space and conditions or the financial resources for installing their own PV system.

[10] Micro businesses employ 10 or fewer people and earn less than $4 million Mexican pesos in annual revenue. "Small" Businesses employ 11–50 people and have an annual revenue of $4.01–$100 million Mexican pesos (Banco de Mexico 2017).

With its high solar resources, Mexico could potentially utilize the community solar model to increase DG deployment and in particular help achieve the goal of democratization of energy reform by bringing clean energy to segments of the population other than the high-consumption customers (which are often high-income households), and potentially as a reduction mechanism for the high electricity subsidies by reducing the number of kWh that would receive federal subsidies. Community solar projects also benefit from economies of scale and could provide advantages to the system operator (CENACE) to best understand, manage, and integrate DG into the electrical system. While the energy reform allowed for the creation of community solar systems, the CRE has not yet enacted the appropriate regulation to allow virtual net metering, which is essential for community programs. States in the peninsula could collectively bring up this issue to the CRE and look into forming partnerships with the basic service utility (CFE), the private sector, and not-for-profit organizations to kickstart a series of DG pilot community solar projects of 500 kW in state or municipality-owned land to understand the benefits and build the foundation for larger deployment.

### 2.2.4 DG Public Policy Options for the Peninsula States

Public policy is one mechanism that state energy offices can utilize to reduce barriers and promote investment to increase deployment of DG technologies. NREL has previously examined the DG policy landscape in Mexico and published a paper describing policy options based on lessons learned and international best practices.[10] Although this paper was written with the federal government in mind, some of the discussed options could be adapted as a base for state-sponsored legislation to promote and expand the market for DG in the region.

1. **Reduce financial barriers to DG adoptions through direct financial incentives and expanding access to affordable financing:** Financial barriers are found to be some of the biggest obstacles for adoption. The states in the Peninsula could potentially establish *direct financial incentives* in the form of tax credits or exemptions, similar to what the city of Merida is doing with the discount on property taxes for businesses that install qualifying technologies. Such incentives help lower the cost of DG systems, making them affordable for a larger segment of the population. Financial incentives can also be offered to specific segments such as low-income populations and micro-businesses. This type of support has been shown as an effective mechanism to reduce inequality in the adoption of DG PV technology.[11] Another option is to help *expand access to financing* of DG technologies. Upfront costs of PV systems, although in a declining trajectory, may still present a barrier for adoption for some customers. Medium-term loans are effective for helping potential DG adopters distribute the initial costs along the term of the loan, but affordable financing in developing countries can be hard to achieve because of high interest rates or lack of interest from commercial banks. Although at least one bank in the Peninsula is already offering loans for DGPV systems, the Peninsula states could step in and work with regional banks to reduce the risk of the investment and help customers that would otherwise not qualify for a commercial loan. Peninsula states could study the possibility for setting aside and using state resources and/or partner with private developers interested in growing the DG PV market and create a revolving fund for the purpose of providing financing to some sectors of the population.
2. **Support industry growth and quality of DG installations through workforce training programs**: A barrier also found in a nascent DG PV market is the quality of the installed product due to the scarcity of trained professionals with experience in PV installations. The states could increase the quality of DG PV installations and the confidence of potential customers and financiers by introducing trainings and certification programs with the assistance of technical institutions and universities.
3. **Promote public awareness of DG technologies:** Another role the states could take is to increase public awareness and education of solar DG, including: basic concepts of irradiation and electricity generation, safety and proper installation, economic and environmental benefits, and

job creation opportunities. The promotion could be done through the creation of a website and the use of public campaigns that could include the promotion of state incentives and programs that the states may be adopting.

4. **Advocate for streamlined interconnection processes and attractive compensation rates for DG:** The three states could also band together to work with CFE and the federal government to adopt interconnection practices and compensation rates that help promote the adoption and expansion of the market in the Peninsula.

### *2.2.5 Energy Efficiency*

The implementation of energy efficiency programs and measures in the Yucatán Peninsula can reduce electricity consumption in residential, commercial, and industrial buildings and installations while creating new business opportunities and well-paying jobs. Energy efficiency, together with deployment of clean generation, is seen as a key component of the long-term sustainable state development programs for the three states in the Peninsula. The inclusion of energy efficiency policies in their energy plans and the adoption and implementation of energy efficiency measures complement other energy-related policies, such as increasing clean generation, reducing energy prices, and increasing energy security, reliability, and resilience in the region. Nonetheless, there are some key barriers for the implementation of energy efficiency that must be understood and reduced. These barriers are not unique to the Peninsula or to Mexico and include: access to affordable financing,[11] high upfront investment, operation and maintenance costs, scarcity of available fiscal incentives, and lack of technical knowledge from finance institutions to energy consumers.

In Mexico, the National Commission for the Efficient Use of Energy (CONUEE) is a decentralized administrative body of SENER, whose main objective is to promote energy efficiency and act as a technical body for the sustainable use of energy. Among its competences, the following are important to mention:

- Issuance and verification of general administrative provisions regarding energy efficiency and activities that include the sustainable use of energy.
- Issuance and revision of Official Mexican Standards on energy efficiency.
- Technical advice on sustainable use of energy to the agencies and entities of the Federal Public Administration, as well as to the governments of the states and municipalities that request such advice.
- Preparation and publication of books, catalogs, manuals, articles, and technical reports on the work carried out in the area of energy efficiency.
- Carry out technical studies required to determine patterns and intensity of energy consumption by end use, type of user, economic activity, and region of the country.
- Promotion and arrangement of voluntary instrumentation of energy management systems under internationally recognized procedures, protocols, or standards.
- Creation and strengthening of capacities of public and private institutions of a local, state, and regional nature so that they support energy efficiency programs and projects in municipal services and small- and medium-sized enterprises.
- Identification of best international practices regarding energy efficiency programs and projects and promotion of applicable practices in the national territory.

[11] In the commercial financial sector, many institutions are unaware of the benefits and bankability of energy efficiency projects. In many countries, these barriers have been reduced with training and seminars for commercial banks on energy efficiency technologies that open the door to funds for these projects.

Within the framework of the Energy Efficiency Program for the Federal Public Administration, the CONUEE issues and publishes in the Official Federal Gazette, the documents that establish and regulate the various energy saving actions to must be carried out by federal institutions.

At the subnational level, the official Mexican standards (NOM) and the voluntary application standards issued by CONUEE are only mandatory if the states decide to adopt them. With respect to energy efficiency standards in state buildings, several Mexican states have written their state standards with the adoption of the standards made by CONUEE and present the NOM contained therein as mandatory. State autonomy allows each state and municipality to decide within its own legal framework whether it requires the NOM or not.

In this section, we discuss some useful approaches to help the Peninsula states through the policymaking process. We follow with more detailed discussions on energy efficiency policy and program-making information in the priority sectors of low-income housing, government buildings, small businesses and water pumping systems. At the end of the report, we include Appendix A with more detailed technical information that complements the discussion. Future energy efficiency work in the peninsula could include review and adoption of CONUEE NOMs and other international best practices, design of programs for promotion of energy efficiency in various sector of the economy, education of consumers and financial institutions, and energy audits.

#### *2.2.5.1 Energy Efficiency Policy Approaches*

Deciding how and where to start implementing programs requires careful planning and prioritization. Methods of outreach and evaluation, for example, have important roles to play and should be analyzed when new policies are considered. (Aznar, Logan, Gagne, Chen – 2019 Advancing Energy Efficiency in Developing Countries). Energy efficiency investments can provide concrete benefits in terms of reducing overall energy demand and meeting national energy security and environmental protection goals (USAID 2020). In addition, energy efficiency programs and investments can be explored in tandem with existing incentives and programs for DG deployment as long-term systematic solutions to reduce the federal electricity subsidies in an economic and efficient way.

The American Council for an Energy Efficient Economy has created a series of documents that facilitate analysis and decision-making to design energy efficiency policies (ACEEE YEARs). In particular, they have designed a tool that mentions the following several steps to develop the theme of energy efficiency in cities, which provides important lessons to the states of the peninsula:

- Develop, implement, and communicate an energy efficiency vision for the state.
- Increase energy efficiency in local government operations.
- Increase energy efficiency in existing buildings.
- Work on the implementation of energy efficient practices, equipment, and materials in new construction.
- Promote transport with energy efficiency.
- Leverage and maximize federal programs.

When developing energy efficiency programs, it is important to tackle the barriers that could derail adoption. The following is a useful list to consider (Cooperación Alemana and GIZ 2018):

1. Develop a portal with information on successful business models that promote the adoption of energy efficiency:

   A. Disseminate the experiences of other countries in the implementation and development of specific markets and industries.
   B. Identify capacity building needs for each sector and define a joint program.
   C. Conduct working group meetings with key sector leaders to identify whether there are specific barriers that have not been detected in this study.
2. Develop dissemination workshops on available technologies to provide training for the implementation of best practices by the type of industries covered:
   A. Incorporate technological tool systems with the participation of research and academic institutions to create a "train the trainer" program to extend the outreach and adoption of these tools.
   B. Identify energy infrastructure restriction situations and their possible solutions.
   C. Conduct opportunity analysis for the implementation of publicly funded audits to identify opportunities.
3. Conduct an in-depth analysis of financing problems:
   A. Identify whether the source is a problem of access to financing, lack of commercial banking capacity, or inherent costs of financing.
   B. Develop lines of financing through the support of national, regional, or international development banks and training of commercial banks.
   C. Analyze strategies to facilitate access to credit for small industrialists for the purchase of efficient equipment.
   D. Identify with the stakeholders the type of financing that would facilitate a favorable decision.
   E. Define performance and guarantee contracts on associated risks and lines of credit tied to concessional rates. Creation of specific lines in first-tier banking so that commercial banks have credit lines tied to the purchase of certified efficient equipment or credit lines for the implementation of more efficient production processes.
   F. Evaluate access and establish partnerships with international development banking institutions to create guarantee funds to reduce risk and its perception.
   G. Evaluate the reduction or elimination of other tax burdens to create an incentive pathway for the adoption of these technologies.
   H. Develop special amortization regimes for different components of capital. This will attract major banking institutions to actively participate on these programs.
4. Create directories of energy service corporations (ESCOs) and a guarantee fund to facilitate financing and support for ESCOs:
   A. Identify capacity development needs for the existence of ESCOs.
   B. Enhance the outreach and bridge the gap by bringing the ESCOs and industries to work together cohesively.
5. Create databases of equipment and suppliers in both the local and international market. Identify cutting edge technologies that enhances the state of the art.
6. Analyze the feasibility of the state to operate as a guarantor in such a way as to reduce the risk of private companies and that this allows them to access credits at more convenient rates.

#### 2.2.5.2 Energy Efficiency for the Benefit of Low-Income Households

Low-income residential consumers in developing nations may face decisions between paying the electric bill and giving up other services or basic necessities such as heating, medicine, food, or education. Organisation for Economic Co-operation and Development countries have addressed these competing needs through a variety of approaches that fall into two broad groups: (1) electricity subsidies provided as assistance through a reduction in electricity bills for low-income consumers, and (2) investments in energy efficiency that provide a long-term reduction in the energy that the customer pays on their bill. Electricity subsidies might still be needed when energy efficiency policies and programs do not reach all consumers in need (Aznar, Logan, Gagne, Chen – 2019 Advancing Energy Efficiency in Developing Countries).

Mexico's electricity subsidy reduces the government's capacity to invest in other national necessities and programs. Energy efficiency measures and programs targeted at low-income customers may have the potential to reduce electricity consumption, and, therefore, the ongoing government outlay required for electricity subsidies. Peninsula states can analyze a variety of low-income energy efficiency measures and programs to understand which are the most impactful. One option could include mandates for energy efficiency construction codes for low-income housing, even considering the installation of distributed PV. The expected increase of air conditioning use in the Yucatán Peninsula and the resulting additional electricity load and cost underscore the importance of meaningful, cost-effective energy efficiency measures for residential consumers;  especially to low-income customers.

#### 2.2.5.3 Energy Efficiency in Government Buildings and Buildings

Energy use is one of the most important budget items for Mexican states and municipalities. Some of the most notable examples are public lighting, water services (pumping, irrigation, wastewater treatment), and electricity use in public offices, schools, and hospitals. State energy efficiency programs for buildings and public facilities are important to reduce these costs. Effective program implementation requires consultations with various ministries and the company that provides the electrical service. Much can be learned from existing federal and state energy efficiency programs in Mexico. For example, CONUEE has an Energy Efficiency Program in the Federal Public Administration that promotes energy savings and efficient use activities in 1,064 federal government buildings. In 2015, The Local Governments for Sustainability, in coordination with CONUEE, implemented in the states of Jalisco and Tabasco a program similar to that of the Federal Public Administration for public buildings under the administration of these entities (IADB, 2020 Roadmap for the Energy Program of the State of Quintana Roo).

Currently, the states of Campeche, through the Secretariat for Sustainable Energy Development, and Yucatán, through the Secretariats of Sustainable Development and Economic Development and Labor participate in the Climate Action Program for Cities, supported by the Building Energy Efficiency Accelerator (PACC-BEA). The program is implemented by Sustainability for Mexico AC in alliance with World Resource Institute Mexico. The PACC-BEA aims to support and advise local governments in the design and implementation of energy efficiency policies in the building sector, as well as to contribute to the understanding between governments, private, and social sectors to work together to achieve more efficient, sustainable, and comfortable buildings. The program has so far created alliances with the private sector and sustainable organizations to generate public energy efficiency policies in these states of the Peninsula.

The PACC-BEA proposed Campeche as the first state under the "Deep Engagement" project to contribute to the energy efficiency goals of the state. In March 2021, the governor of Campeche signed the general energy efficiency guidelines for state buildings. The guidelines, mentioned below, apply to construction, leasing, maintenance of real estate, acquisition of equipment, materials, and other, and establish the technical criteria that allows improving the efficiency and energy consumption of public buildings. They also will translate into better energy performance, greater thermal comfort, and budget savings through lower energy consumption in the construction and operation of public state buildings.

- Implement an energy management system.
- Improve energy performance in lighting, air conditioning, location, thermal insulation, miscellaneous use, and other uses.
- Increase thermal conformity and reduction of energy consumption.
- Reduce greenhouse gas emissions in the construction and operation of public buildings.
- Priority use of renewable energies.

In Campeche, the PACC-BEA also launched a pilot project called "Energy Management System in the Government Palace of the State of Campeche." In this pilot, the manual for the energy management system that will be implemented has been completed and is under review by CONUEE. The pilot project includes the design and implementation of an energy management system at the Government Palace, which will serve to articulate the energy efficiency guidelines for all state public administration buildings. The pilot project involves evaluating the energy performance; streamlining and reducing energy consumption; implementing improvement actions; developing follow-up mechanisms; and laying the foundation for a deployment to all public buildings of the state public administration.

In addition to leveraging federal CONUEE and state PACC-BEA building efficiency programs, states can initiate two other practices that affect energy use in government buildings: energy audits and building codes. *Energy audits* are an important tool for states to understand their energy load baseline. States in the Peninsula could also use tools like the Lawrence Berkeley National Laboratory (Berkeley Lab) and Johnson Controls, Inc. *Building Efficiency Targeting Tool for Energy Retrofits*, which provides commercial, institutional, and government building owners and managers with an easy-to-use, open-source tool to analyze efficiency improvements by converting available monthly energy consumption data into targeted, cost-effective recommendations for improving energy efficiency. *Building codes* influence building construction methods, required technologies and materials to be used, safety and durability, and have implications on energy and water use.

#### 2.2.5.4 Energy Efficiency in Small- and Medium-Sized Enterprises

Small and medium-sized enterprises in Mexico constitute 99.8% of all companies, generate 52% of the gross domestic product, and contribute 72% of formal jobs (Ministry of Economy). SENER's 2009 National Energy Balance and CFE's 2009 Annual Report show that the energy consumption of the sector represents 17% of the country's energy consumption, which is divided into 11% of the total national thermal energy consumption and 47% of the total national electricity consumption. An estimate of energy efficiency measures in this sector estimates the feasibility to achieve electrical energy savings in small- and medium-sized enterprises of between 10% and 20% (SENER).

To achieve the biggest savings, it is necessary to coordinate with CONUEE in the adoption of energy efficiency standards and to encourage the use of DG. State governments can help by creating energy efficiency programs implementing the best standards and organizing trainings to provide information to small- and medium-sized enterprises and financiers.

#### 2.2.5.5 Evaluation of Energy Efficiency in Water Pumping Systems

Water pumping and treatment is an energy-intensive practice and excellent target for energy efficiency measures. In 2014, the National Association of Water and Sanitation Companies launched the CEEPA initiative and a tool ("Calculation of Energy Efficiency and Energy Saving Potential in Water pumping systems") that allows users to identify the most economical and impactful energy efficiency options and generate reports. Peninsular states can use this tool to identify attractive energy solutions for water pumping.

Some of the most important energy efficiency measures and best practices for water pumping stations consist of integration of relevant regulations or standards, control and maintenance with creation of logs in the operation of water pumping stations, development of best practices and investment solutions for replacement of motors and pumps, adequacy of electricity tariffs, adoption of independent distributed energy in areas such as wells without access to the electrical system, reduction of losses, development and adoption of comprehensive maintenance plans, and others (Cooperación Alemana and GIZ 2017).

### 2.2.6 Sustainable Transportation

Electrifying the transportation sector can be a pillar of regional decarbonization. Not only are electric vehicles more efficient (per joule of energy) than gasoline/diesel vehicles, they have no tailpipe emissions (e.g., NOx, SOx, particulate matter, etc.) that contribute to poor local air quality and overall produce fewer greenhouse gas emissions than conventional vehicles.[12] Despite these benefits, there are barriers and challenges to their deployment such as higher upfront costs, potential range anxiety, charging inconvenience, and general consumer unfamiliarity that may require targeted policies to address.

There are several federal, state, and local policies in place in Mexico that incentivize the deployment of advanced energy vehicles, namely electric, hybrid, and fuel-cell vehicles. At the federal level, Mexico's federal income tax law exempts electric vehicles and hybrids from sales or import fees (Secretaria de Hacienda y Credito Publico 2014). Similarly, a federal income tax law approved in 2017 allows higher tax deductions for electric vehicle and hybrid owners and provides a 30% tax credit for investment in public electric vehicle supply equipment. More recently, the federal government declared an exemption of import taxes to all new electric vehicles for the transport of 10 or more people and the transport of merchandise (Secretaría de Gobierno 2020). At the state level, electric vehicles are exempted from state ownership taxes in the Yucatán and other states. Furthermore, CFE enables electric vehicle deployment by installing a special meter for electric vehicle owners that keeps electric vehicles on the domestic tariff instead of the high consumption tariff so that electric vehicle adopters avoid electricity cost increases. Lastly, Mexico City has led the way in local electric vehicle-friendly policies, including: (1) the exclusion of electric vehicles and hybrids from vehicle verification proceedings (i.e., these vehicles can circulate daily); (2) an EcoTag program that permits electric vehicles to use urban highways at a lower cost; (3) preferential parking status; and (4) exemptions for public and private transit operators using electric vehicles from the requirement to renew their fleet every 10 years (Tellez Martine and Vazquez 2018; Aleatica 2017).

In their 2012 report for the Institute of the Americas, Shapiro and Campero identify four approaches that municipal governments can take to encourage electric vehicle adoption by private and public fleets in Mexico (in addition to federal and industry-led action) (Shapiro and Campero 2012):

- Establish standards, codes, and procedures that streamline the installation and maintenance of charging stations in conjunction with CFE.
- Allow electric vehicles in high-occupancy vehicle lanes.
- Establish dedicated parking for electric vehicles.
- Emulate the Mexico City program that provides an economic incentive and guaranteed loan program to taxi drivers willing to adopt electric vehicles; and/or expand this type of program to other fleets.

[12] The cleaner the grid mix, the greater the emissions reductions of EVs.

There has been little formal emphasis on transportation electrification among the states and cities of the Yucatán peninsula.

The city of Mérida has Plan Integral de Movilidad Urbana Sustenable Mérida 2040 whereby urban mobility goals, strategies and actions are laid out. None explicitly address transportation electrification, but electrifying vehicles could contribute to several strategies, in particular (Ayuntamiento de Merida 2019):

- Optimization and innovation of technologies in the public transport system, with an emphasis on renovating fleets to meet energy efficiency and emission reduction goals.
- Emphasis on monitoring and reducing environmental impacts (e.g., emissions) from private vehicles.

Plan Integral de Movilidad Urbana Sustenable points out that 47% of modal share in Mérida is public transit and 31% private vehicles (with a notable increase in motorcycles), which suggests that these modes of transit could be a target for vehicle electrification pilots or programs should the city be interested in this action.

In Quintana Roo, there is no explicit policy support for electric vehicles, but the state's "Ley de Movilidad" paints broad strokes about the importance of considering environmental impacts, emissions, and sustainable technologies that could justify electric vehicle programs (Instituto de movilidad del estado de Quintana Roo 2019). According to the Secretary of Energy, the state and private sector are interested in promoting electromobility in Quintana Roo, although various barriers remain including potential resistance from public transit labor unions and a paucity of publicly available charging stations for private electric vehicles. Quintana Roo's Instituto de Desarrollo Financiero has recently participated in a Tesla-led initiative to promote electromobilty by installing charging stations.

Understanding the types of registered vehicles in the Peninsula can guide decision-making on electric vehicle policies and programs. This information could indicate which vehicle sectors (e.g., oficial, público, particular) and which type of vehicle (e.g., automoviles, camiones, motos) could be targeted for electrification. Decision makers will have to weigh many factors to determine where to target. Some vehicle types or sectors may be easier to electrify initially than others.

In addition to the general recommendations outlined by Shapiro and Campero (2012), the Peninsula states and in particular Quintana Roo could consider additional transportation electrification measures that could fortify economic development, particularly tourism, in the region, including:

1. Exploring the feasibility of public electric vehicle supply equipment along major corridors that connect three main cities in the Yucatán to enable mid-long distance electrified transport within the region. Mexico's federal government has prioritized transportation infrastructure projects in the Yucatán, as demonstrated by plans for the Tren Maya, intended to link tourist attractions and communities. Electric vehicle supply equipment and electric vehicle travel could be rolled out in a complementary way to this infrastructure project.
2. Pilot the electrification of certain vehicle fleets such as transit buses, taxis (particularly ones that serve airports), municipal vehicles, and motorcycles. Fleets are often early adopters of electric vehicles because of their consistent travel patterns and (typically) ability to be centrally charged and managed. Electrification of transit buses along popular routes and/or taxis or hotel shuttles that travel to and from airports to tourism hubs also raise the profile of electric vehicles among the public, supporting greater familiarity with this new technology.

# 3 Future Work

The assessment provided and the menu of options for possible development is the first step in the 21CPP Mexico program to provide technical assistance to the states of the Yucatán peninsula. The states of the peninsula have some unique differences but share many common areas. This work is intended to help the states to prioritize the next steps and may include some of the following activities:

- Together with state energy officials and the local CENACE, the development of deeper analysis, including a regional renewable energy futures study, where various renewable penetration scenarios, gas supply and price scenarios, location scenarios for the two proposed CFE power plants, and so on, could be modeled to understand their impact on energy security, reliability, environmental impacts, and prices.
- Definition and mapping of areas to be considered for predevelopment of utility scale and DG wind and solar projects, based on land ownership, exclusions, transmission capacity in the area, environmental and social impacts, and so on.
- Capacity building, models, and tools to be used by state energy officials.
- In collaboration with states and other donors in the region, the development of programs, policies and business models that fit state and regional energy priorities.
- Creation of pilot programs like ejidos solares for state clean energy procurement.
- Analysis of the distribution grid capacity and development of programs to monitor solar PV impacts in the network.
- Capacity building and collaboration for effecting energy audits and proposing energy efficiency solutions and financing mechanisms.
- Analysis of potential subnational policies and incentives to create sustainable transportation programs.

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# Appendix A

## Best Practices and Energy Efficiency Solutions per Type of System

The different industries and economic zones of the region have a critical role to play in the adoption and deployment of energy efficiency measures. Adopting these measures will result not only with the important objective of obtaining energy savings and therefore improving its competitive position, but even beyond that, it will resonate in many social aspects that will restore the quality of life of the communities in the southern states of Mexico, especially under the new pandemic context. A potential list of energy savings measures useful to the states of the peninsula are listed below to obtain the greatest impact.

### *Electrical Substations and Electrical Distribution*

1. Redistributing loads in transformers. This consists of avoiding the operation of overloaded transformers or under load, distributing the loads connected to them.
2. Correcting the phase imbalance. This consists of preventing three-phase electrical equipment from being fed with a different voltage value in each of three phases.
3. Regulating the supply voltage. This is to avoid the voltage varying too much within the company.
4. Installing capacitor banks in substations. The capacitor bank is an accessory used to improve the power factor of a company; the context refers to when it is installed in the reception of electrical energy for the entire company.
5. Installing capacitor banks in private equipment.

### *Compressed Air Systems*

1. Install high-efficiency motors in the compressors.
2. Substitute compressors for others of energy-saving technology. This consists of changing compressors for others that consume less energy.
3. Reduce or eliminate leaks. This refers to reducing or avoiding compressed air that escapes without being used in pipes, accessories, and equipment.
4. Automate the operation of compressors. This refers to installing equipment to automatically regulate the compressor operation.
5. Adapt the system capacity to the real compressed air needs. This consists of correcting the compressed air system by making its capacity correspond to the needs of the system.
6. Install storage tanks. This consists of the installation of a tank to store compressed air, thereby reducing compressor loading times.
7. Modify the distribution system with saving criteria. This consists of making changes to reduce losses in the compressed air system.
8. Modify pipes.
9. Reduce the distribution path.
10. Reduce valves and accessories.
11. Install variable speed (frequency) drives and electronic speed variators.

### *Pumping Systems*

1. Install high-efficiency electric motors in pumps.

2. Match engine power to pump-driven load. This refers to the pumps having an electric motor of adequate electrical power.
3. Substitute current pumps for others that work more efficiently. This consists of changing pumps for others that consume less energy.
4. Reduce or eliminate leaks. This refers to reducing or avoiding liquids that run off without being used in pipes, accessories, and equipment.
5. Automate the pumping system operation.
6. Adapt the system capacity to the real pumping needs.
7. Modify the distribution system with saving criteria.
8. Install electronic speed variators.

### *Refrigeration*

1. Install high-efficiency motors in the compressors.
2. Install high-efficiency motors on chilled and return water pumps.
3. Install high-efficiency motors in cooling tower fans.
4. Substitute compressors for others of greater efficiency.
5. Install thermal storage systems, such as ice banks.
6. Check adequacy of engine power to load driven by compressors.
7. Automate the control system, taking unnecessary compressors out of operation.
8. Clean evaporators and condensers.
9. Install or correct the thermal insulation of ducts, cylinders, or pipes.
10. Isolate tanks, cold rooms, ice banks, and other equipment.
11. Install insulating curtains on entrance doors to cold rooms.
12. Control air circulation over the stored product.
13. Precool water or air.
14. Install electronic speed variators in compressors, fans, and pumps.

### *Air Conditioner*

1. Install high-efficiency motors in the compressors.
2. Install high-efficiency motors in chilled water pumps.
3. Install high-efficiency motors in the air handlers.
4. Substitute compressors with other energy-saving technology. This consists of changing compressors for others that consume less energy, for example, reciprocating screw type or centrifugal ones.
5. Install a thermal storage system, such as ice banks. This consists of storing the cold in tanks or warehouses and then taking advantage of it to reduce the demand for energy at the critical or most expensive moments.
6. Ensure adequacy of engine power to load driven by compressors. This refers to the compressors having an electric motor of adequate electrical power.

7. Automate the control system, taking unnecessary compressors out of operation. This refers to reducing the number of compressors in operation, avoiding working compressors unnecessarily, even for periods.
8. Clean evaporators and condensers. This consists of carrying out a systematic cleaning of the evaporators and condensers of the refrigeration system to eliminate incrustations.
9. Install thermal insulation on walls and ceilings. This is about thermally insulating the walls and roofs of the conditioned building.
10. Maintain the thermal insulation of ducts or pipes. This refers to maintaining thermal insulation in the various components that drive the air conditioning in perfect condition.
11. Apply reflective film on windows to reduce heat input. This is about
12. Place a film that rejects solar radiation that falls on the windows.
13. Precool water or air. This consists of carrying out the cooling process in two or more stages, thus avoiding large differences between the initial temperature of the air or water and the temperature that it must reach.
14. Install electronic speed variators in compressors, air handlers, and pumps. This consists of the installation of electronic control equipment called the "variable frequency converter or electronic speed variator," which controls the speed of the electric motor of this equipment.

### Illumination Systems

1. Installation individual dampers to control areas. This consists of placing switches in offices, classrooms, auditoriums, and all areas where the lighting can be turned off individually.
2. Replace incandescent bulbs with LEDs.
3. Replace fluorescent lamps with other linear ones (T-8) of higher efficiency. This consists of changing conventional fluorescent lamps for others that, with less electrical power, give equal or more light.
4. Replace mercury vapor lamps with high-pressure sodium lamps.
5. Replace mercury vapor lamps with metallic additives.
6. Install specular reflectors, reducing the number of lamps. This consists of reducing the number of fluorescent tubes per luminaire by adding a specular aluminum reflector that reflects the light that falls on it.
7. Replace conventional ballasts with energy-saving ballasts. This consists of replacing the ballast of the lighting systems with another that consumes less energy.
8. Install presence sensors. These turn on the light when they detect human presence and turn lights off when the area is unoccupied.
9. Install intensity reducers (dimmers) for lamps. This equipment is used to reduce the light intensity of some lamps, at the same time reducing the energy consumed.
10. Install photocells to turn off lighting in areas that receive good natural light.
11. Install sheets or translucent domes. These sheets allow the passage of natural light, enabling occupants to turn off interior lights.
12. Apply scheduled shutdown controls based on schedules or company policy. These are measures of turning off or turning on lights by schedules or when the area is left without personnel working.

13. Install a general lighting control system. This is computerized equipment that allows occupants to turn off lights by schedule, presence, natural light, and telephone, among others.

### Production Processes

1. Replace electric heating elements by infrared technology. Infrared technology consists of heating based on infrared radiation, emitted by quartz tubes or similar equipment.
2. Substitute electric heating elements for heating with a fuel such as LP gas, natural gas, diesel, or another. This consists of changing the heating processes that use resistors for others that use LP gas, natural gas, diesel, or other as an energy source.
3. Substitute standard motors for high-efficiency ones.

# Appendix B
## Overview of Mexico's Power Generation

As the states of the Yucatán Peninsula weigh their sustainable energy options, the power generation capacity and annual production for all of Mexico can provide valuable perspective. For a fleet of power plants, capacity is designated by the sum of nameplate ratings that represent the short-term (hourly) maximum amount that a given power plant can produce electricity, restrained by environmental or operating restrictions. As illustrated in Figure B- 1 for 2014 through 2018, fossil fuel and renewables form the basis of nearly all of the electric generating capacity in Mexico, supported as well by a small amount of nuclear capacity. Figure B- 2 provides granularity for the renewable power generating capacity for the country over the same time period.

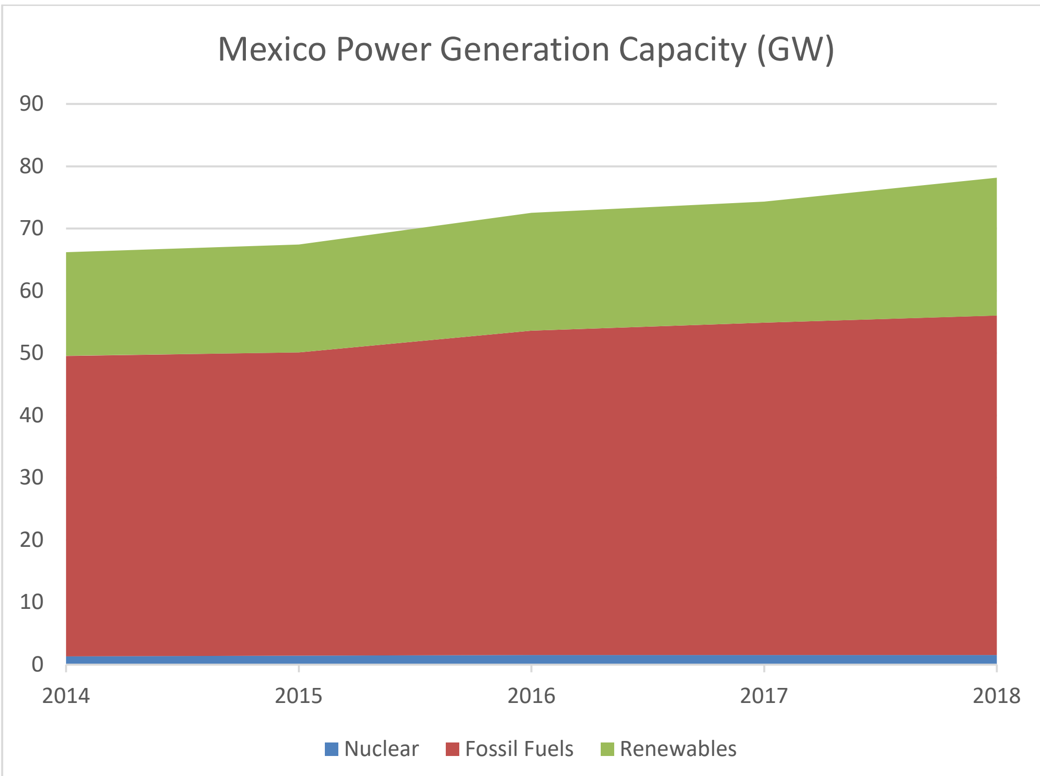


**Figure B- 1. Mexico's annual clean energy[13] versus fossil fuel generation capacity**

Source: CFE via EIA

[13] Clean energy in Mexico includes renewable sources, nuclear, and high-efficiency cogeneration

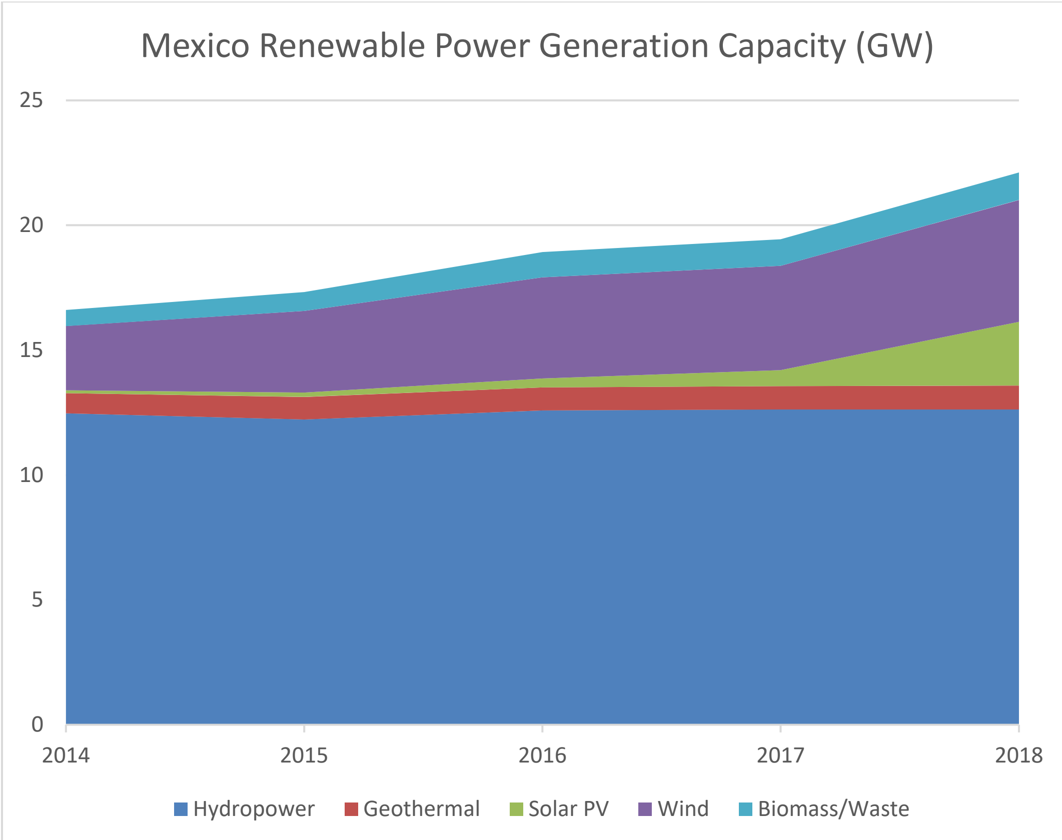


**Figure B- 2. Mexico's annual renewable generation capacity breakdown**

Source: CFE via EIA

As Figure B- 2 shows, hydropower makes up nearly 60% of Mexico's renewable electricity capacity. However, growth of hydropower and geothermal has been modest over the indicated time period while biomass and wind have nearly doubled in capacity, and solar PV capacity was over 22 times greater in 2018 as it was in 2014.

While capacity reflects the short-term capability of a power plant, generation represents the actual long-term production from the power plant. Figure B- 3 illustrates actual annual power production for Mexico from 2014 through 2018. Of the growth in power generation that occurred during this period (30 TWh), more than 80% of that growth was derived from fossil fuels, and the balance of the growth was nearly evenly split between nuclear and renewables. Figure B- 4 provides granularity for the renewable electricity production from 2014 through 2018.

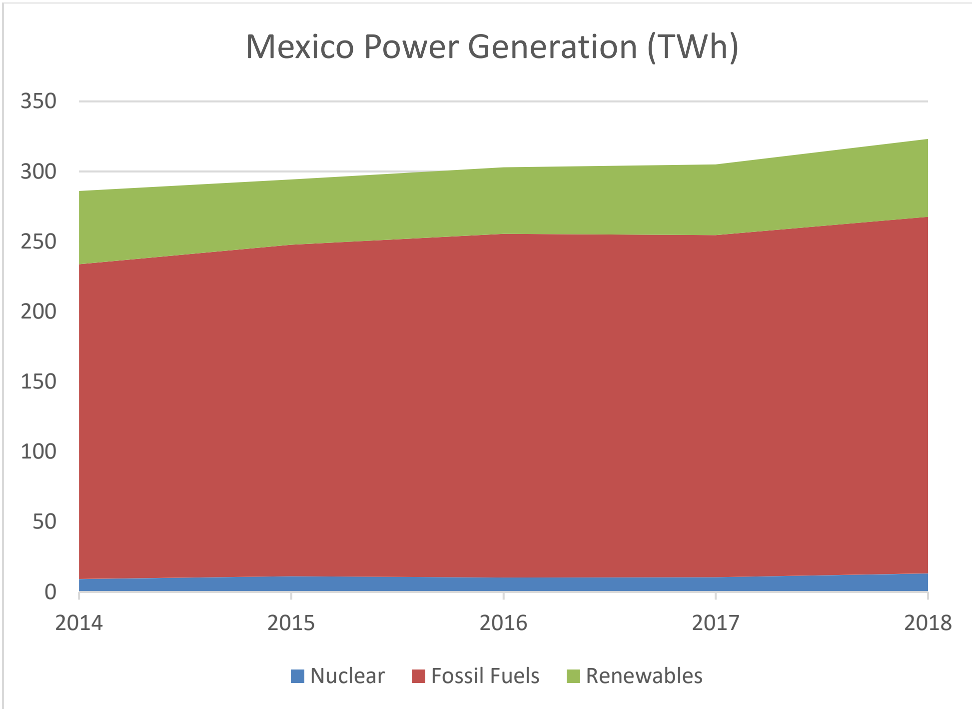


**Figure B- 3. Mexico's annual clean energy generation versus fossil fuel-based generation**

Source: CFE via EIA

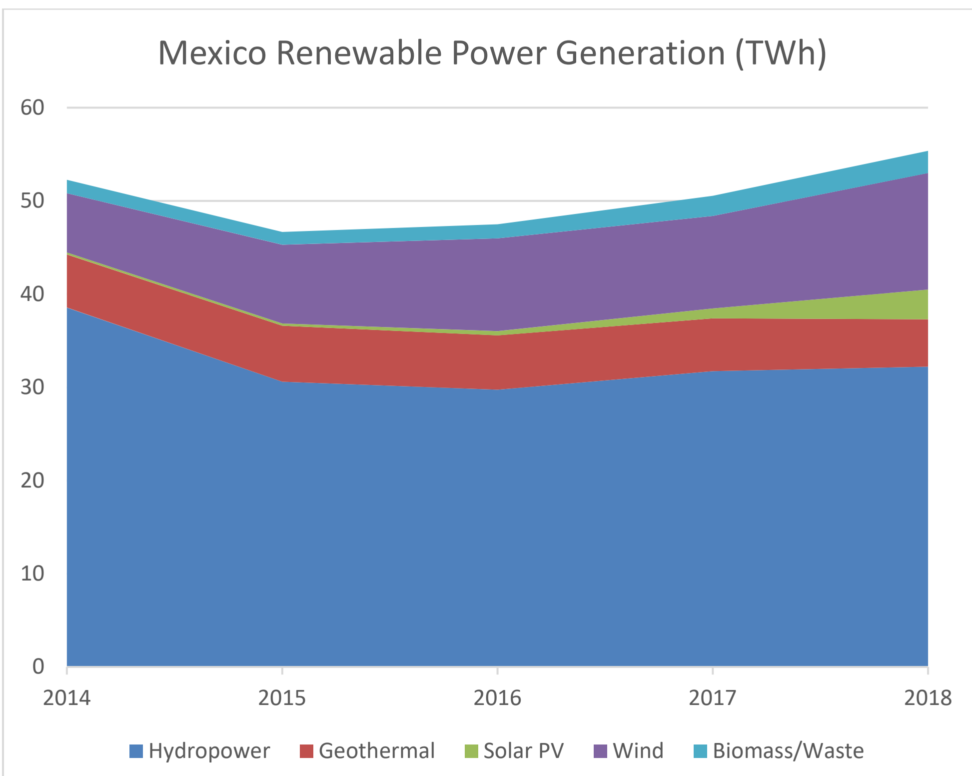


**Figure B- 4. Mexico's annual renewable power generation breakdown**

Source: CFE via EIA

As Figure B- 4 illustrates, production of electricity from hydropower and geothermal declined by nearly 7 TWh across Mexico. Hydropower generation decline is mostly attributable to drought years and a growing need for water usage apart from power generation. Production from wind, solar, and biomass increased by more than 10 TWh, predominantly from wind.

Capacity factor is another important concept when reviewing energy options for the Yucatán Peninsula. Capacity factor, expressed as a percentage, is calculated by dividing a power plant's actual annual production by that power plant's theoretical annual production assuming the power plant could be operated at capacity for all hours in a year.[14] While such calculations are most relevant for an individual power plant, we can determine an apparent capacity factor for the electricity generating sector of Mexico and each technology across the portfolio. Figure B- 5 provides the apparent capacity factor for fossil, renewable, and nuclear.

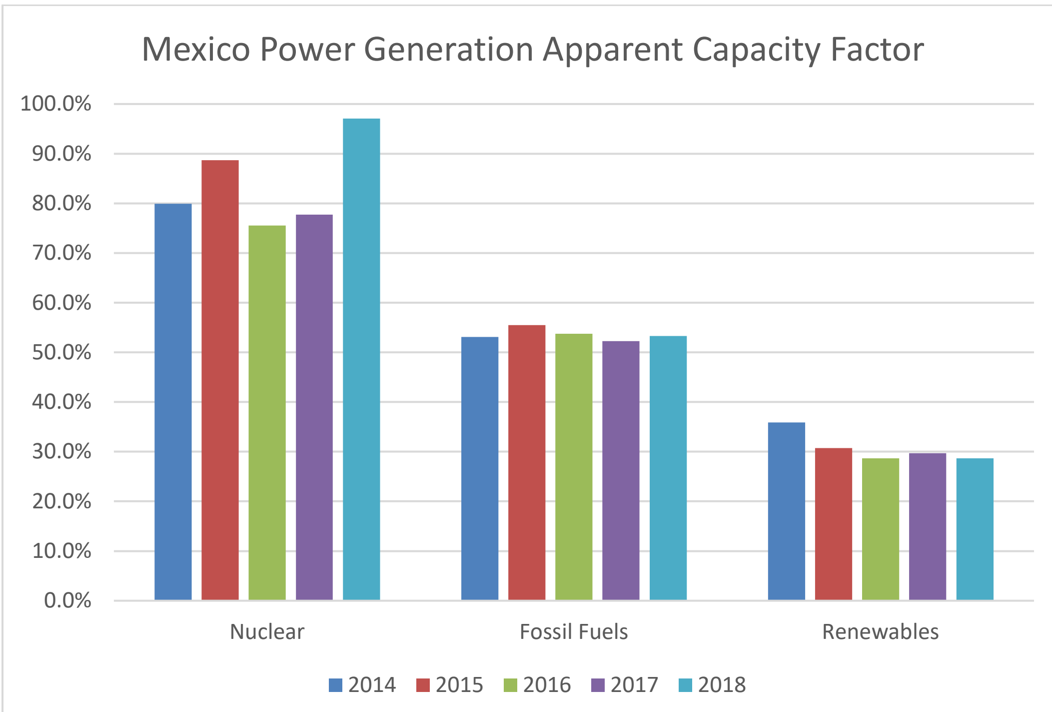


**Figure B- 5. Mexico's annual power generation capacity factor—clean energies versus fossil fuel technologies**

Source: CFE via EIA

Figure B- 5 shows that, as of 2018, Mexico's nuclear fleet was operating at 97% of capacity, fossil generation is 53% of capacity, and renewable alternatives are 29% of capacity. Figure B- 6 provides additional granularity for Mexico's renewable fleet.

[14] Capacity Factor = (Actual Production / (Nameplate Capacity x 8760)) x 100%.

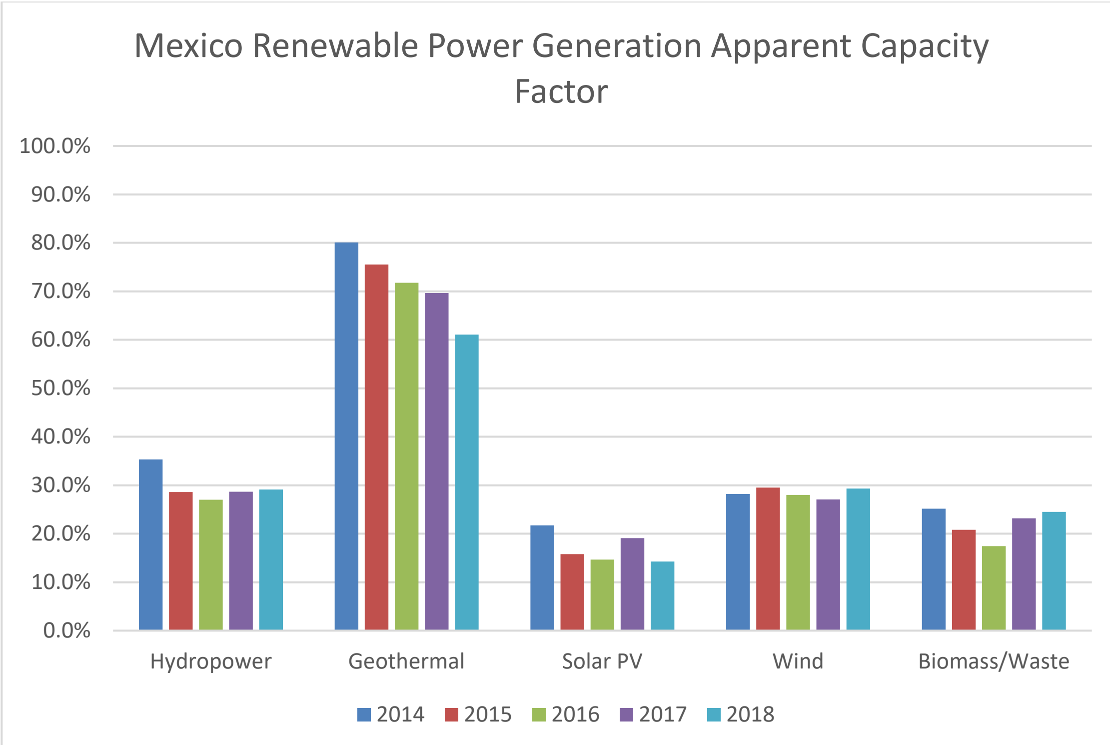


**Figure B- 6. Mexico's estimated capacity factors by renewable technology**

Source: CFE via EIA

The apparent capacity factors presented in Figure B- 6 demonstrate the intermittent nature of various renewable energy options. Geothermal power plants often have the least variability because the subsurface geothermal resource is consistent throughout the year. Hydropower may be variable, depending on rainfall, competing water uses, and other factors. Bioenergy is often tied to growing seasons. Wind energy and solar energy are dependent on the wind blowing and the sun shining.

Apparent capacity factors determined for the various generating technology fleets from empirical data offer useful, if imperfect, insight for a contemplated individual power plant. For example, from the data in Figure B- 6, a wind energy project in Mexico would be expected to produce at a nominal 30% capacity factor over the course of a year, recognizing that production will vary diurnally and seasonally.

Although apparent capacity factors can be useful, there are limitations. First, past performance of existing projects may not ultimately be reliable for a new individual power plant, particularly if the new power plant is not designed well or the resource is of lower quality. Second, in a relatively small and growing market, capacity data will include new power plants that are installed throughout the year and in the process of ramping up to capacity. Thus, the capacity factor will be skewed lower because theoretical production will be calculated as though new power plants were available for the entire year. Data for 2014 through 2018 suggests this to be the case for both wind and solar.

## Reliability With Increased Penetration of Variable Renewable Technologies

The list of clean energy technologies in the Mexican law includes several that are not renewable, for example nuclear and efficient cogeneration. However, the primary role of the electricity sector is to provide reliable and affordable electricity to all customers. In addition to scheduled and unscheduled generator outages, the grid must respond to changes in load as well as variability in resource-dependent generation (such as wind and solar). Variability that can be predicted with a high degree of confidence is addressed through planned energy scheduling such as day-ahead markets and multiyear resource planning. Variability that is short-term and less predictable is addressed in the real-time market and with ancillary services such as those provided by fast-response generation (gas turbines and diesel engines). System reliability is increased by shortening the system dispatch time.

Solar and wind energy contribute to both short- and long-term variability. This variability is managed depending on the level of penetration, but, in general, the system is operated in the same way. The tools that provide added flexibility to the system serve to manage the additional variability brought by solar and wind generation. On average, a 5% to 10% solar and wind generation is unlikely to affect the types and magnitude of reserves required to reliably manage the system. In real systems, it has been observed that when reaching 30% generation from wind and solar, the magnitude and the timing of reserves, including duration, seasonality, and response time, may require some adjustments. Careful planning and operation design around a diverse mix of resources is essential.

Table B- 1 addresses six key renewable energy technologies and general considerations for deployment or expansion in the Peninsula.

**Table B- 1. General Considerations for Renewable Technology Deployment in the Peninsula**

| Technology | Considerations |
|---|---|
| Wind | With over 240 MW of utility-scale wind turbines installed and more in various stages of development, the Peninsula has a strong wind resource that is expected to feature prominently in energy planning. Distributed small- and medium-scale wind may also be feasible. |
| Solar PV | In only a few years, solar PV has grown significantly, demonstrating that the Peninsula has a strong solar resource for energy planning, utility scale, and distributed. Other forms of solar energy are not deemed economically competitive for the foreseeable future. |
| Ocean | Ocean energy remains in a state of development and is not expected to be a near-field opportunity for the Peninsula. It may be a technology worth consideration in the longer term. |
| Geothermal | While Mexico has a strong geothermal resource, the current developable resource on the Peninsula is expected to be limited. |
| Bioenergy | Bioenergy is a category that includes various forms of biomass and waste to energy. Forest cuttings, crop residues, livestock waste, food waste, seaweed, and more can produce energy via direct combustion, anaerobic digestion, gasification, fermentation, and other methods. Though current deployment for power generation is limited, bioenergy is expected to feature prominently in energy planning for the Peninsula, at utility scale and distributed. |
| Hydro | The Peninsula is flat, with limited surface waters. Generally, hydropower requires significant elevation differences. Though there may be opportunities for low-head (low elevation difference) hydropower, distributed small-scale hydropower, and pumped storage hydropower, it is not expected to feature prominently in the energy mix for the Peninsula as it does for Mexico. |

To address the variability of wind and solar, system operators must know and take advantage of the available flexibility in the electrical system. System operators must also apply operational practices and new technologies to allow the integration of higher percentages of variable generation technologies. Some of the changes that a system operator may add include adopting wind and solar forecasting systems, moving closer to real-time electricity markets, adding demand response programs, implementing mechanisms to compensate fossil fuel generator for increased ramping capabilities, and others.

Energy storage such as large-scale batteries or pumped-storage hydropower are technologies that can provide support for renewable energy to deliver dispatchable electricity. As a stand-alone resource attempting to match a 100-MW gas turbine, a solar farm would need to be sized in excess of 500 MW and would require several days of energy storage capacity to accommodate nighttime and cloudy conditions. The capital cost for a solar project of this design might be an order of magnitude higher than a comparable gas turbine project, recognizing that operating costs (fuel) would be considerably higher for the gas turbine project. In reality, the reliable operation of supply and demand of electricity takes into consideration the entire system and renewable power plants are not dispatched as stand-alone generators. Thus, large amounts of renewable power can be safely integrated in the power system. The capacity factor and energy storage issues emphasize the need for a strong planning and design exercise, combined with best operational practices to meet sustainable energy needs at all times and at affordable prices.