
# First Steps in the Smart Grid Framework: An Optimal and Feasible Pathway Toward Power System Reform in Mexico

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**Subcontract Report**
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CLEAN ENERGY MINISTERIAL
Accelerating the Transition to Clean Energy Technologies

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**NOTICE**



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Mexico National Center for Energy Control (Centro Nacional de Control de Energía—CENACE)

Mexico's national smart grid sub-group on policies: Grupo Nacional de Redes Eléctricas Inteligentes – Grupo de Trabajo para Políticas Públicas

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# Abstract

Beginning in 2008, the government of Mexico enacted a series of laws and regulations to reform its energy sector. In 2013, the government of Mexico approved a constitutional energy reform, which included the new Electricity Industry Act that established a competitive wholesale electricity market, creation of an independent system operator, and restructuring of Mexico's vertically integrated utility. At the end of 2015, the Mexican congress approved the Energy Transition Law, which establishes goals for increasing electric generation from clean sources and energy efficiency targets. With the vision to transform the power sector, Mexico included in the new laws and regulations deployment of smart grid technologies and provided various attributes to the Ministry of Energy and the Energy Regulatory Commission to enact public policies and regulation. The use of smart grid technologies can have a significant impact on the integration of variable renewable energy resources while maintaining reliability and stability of the system, significantly reducing technical and non-technical electricity losses in the grid, improving cyber security, and allowing consumers to make distributed generation and demand response decisions, etc.

This report describes for Mexico's Ministry of Energy (SENER) an overall approach (Optimal Feasible Pathway) for moving forward with smart grid policy development in Mexico to enable increasing electric generation from renewable energy in a way that optimizes system stability and reliability in an efficient and cost-effective manner.

## List of Acronyms

| | |
|---|---|
| AMI | advanced meter infrastructure |
| CENACE | Centro Nacional de Control de Energía |
| CFE | Comisión Federal de Electricidad |
| CRE | Comisión Reguladora de Energía |
| DG | distributed generation |
| ESTA | ESTA International, LLC |
| NIST | National Institute for Standards and Technology |
| PMU | phasor measurement unit |
| SENER | Secretaría de Energía, Ministry of Energy |

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# 1 Background

In 2012, Mexico's Comisión Reguladora de Energía (CRE) began to explore the potential to implement smart grid solutions in Mexico and decided to produce a regulatory roadmap for implementation. A consultant for technical assistance, ESTA International (ESTA), was engaged to research and develop the roadmap with the assistance of CRE, Secretaría de Energía (SENER), Comisión Federal de Electricidad (CFE), Centro Nacional de Control de Energía (CENACE), and other major stakeholders in Mexico. "The Smart Grid Regulatory Framework for Mexico" (the "ESTA Roadmap") (ESTA 2014) was completed in September 2014, and Spanish and English versions of the report are posted on the CRE website.[1]

On February 24, 2015, more than 100 energy policymakers, industry leaders, and other stakeholders gathered in Mexico City to discuss the findings of the ESTA Roadmap and the future of smart grid in Mexico (the "Smart Grid Roadmap: Next Steps" conference). The conference report, "The Regulatory Roadmap for Smart Grid in Mexico: Next Steps" (Binz 2015), marked another step in the country's progress toward reform of the energy sector (the *Reforma Energética)* and the introduction of technologies that will modernize the electric grid, improve its operations, and empower consumers. The conference was a working meeting, with workshop sessions designed to assist CRE to prioritize the recommendations of the ESTA Roadmap. The conference participants spanned a wide spectrum of stakeholders in the Mexican electricity sector.

In September 2015, meetings were held in Mexico to create consensus around the best pathway forward for smart grid implementation. This report discusses the outcomes of those meetings.

[1] ESTA Smart Grid Roadmap (Spanish). http://cre.gob.mx/documento/3978.pdf.
ESTA Smart Grid Roadmap (English). http://cre.gob.mx/documento/3979.pdf.

# 2 Overview

The ESTA Roadmap (ESTA 2014) provided a comprehensive vision of electricity sector reform. The conference report “The Regulatory Roadmap for Smart Grid in Mexico: Next Steps” (Binz 2015) captured stakeholder conversations in Mexico discussing prioritization and implementation of the 91 recommendations included in the ESTA Roadmap. These two documents lay the foundation for describing a path forward toward the transformation of the electricity sector in Mexico. The task before SENER, CRE, CENACE, and CFE is now to consider what steps need to be taken in the first three years of the transition.

The purpose of this report is to: (1) suggest to SENER an overall approach (Pathway) for moving forward with smart grid policy development in Mexico, and (2) describe more thoroughly one policy area of particular importance that follows from the Pathway. In this report, we articulate these first steps and explain how success in implementing these first steps should be tracked over time.

In preparing this report, we first met with stakeholders and members of the Grupo Nacional de Redes Eléctricas Inteligentes, Mexico’s national smart grid sub-group on policies. This stakeholder meeting took place in Mexico City in September 2015. We emphasized that several pathways are possible in moving toward and ultimately achieving the energy reform goals, but focused first on four potential pathways for their consideration.

Each of the four pathways incorporates several elements designed to advance Smart Grid and, in doing so, accomplishes certain other thematic purposes. Table 1 lists the four pathways and their associated themes.

**Table 1. Four Sample Pathways and Associated Themes**

| Pathway | Theme |
|---|---|
| Pathway 1 | Improve Status Quo and Reliability |
| Pathway 2 | Improve Customer Choice |
| Pathway 3 | Move Utility Toward Platform Role |
| Pathway 4 | Enable Competitive Markets |

Each of these themes has merit, and none should be neglected in any long-range plan for deployment of a smart grid. However, we also presented a fifth pathway that represents the middle ground, drawing from elements of each of these four pathways. Pathway 5 represents a not too bold, not too soft pathway to change—an Optimal Feasible pathway for smart grid development in Mexico.

We used the 21st Century Power Partnership matrix presented in “Power Systems of the Future” (Zinaman et al. 2015) to organize and articulate the range of possible pathways. The matrix has four quadrants representing four distinct approaches to smart grid development: adaptive, evolutionary, restructured, and revolutionary. These approaches are based on the relative speed of the power system change and depth of the change associated with each approach. Each of the five pathways was mapped to these approaches as shown on the matrix in Figure 1.

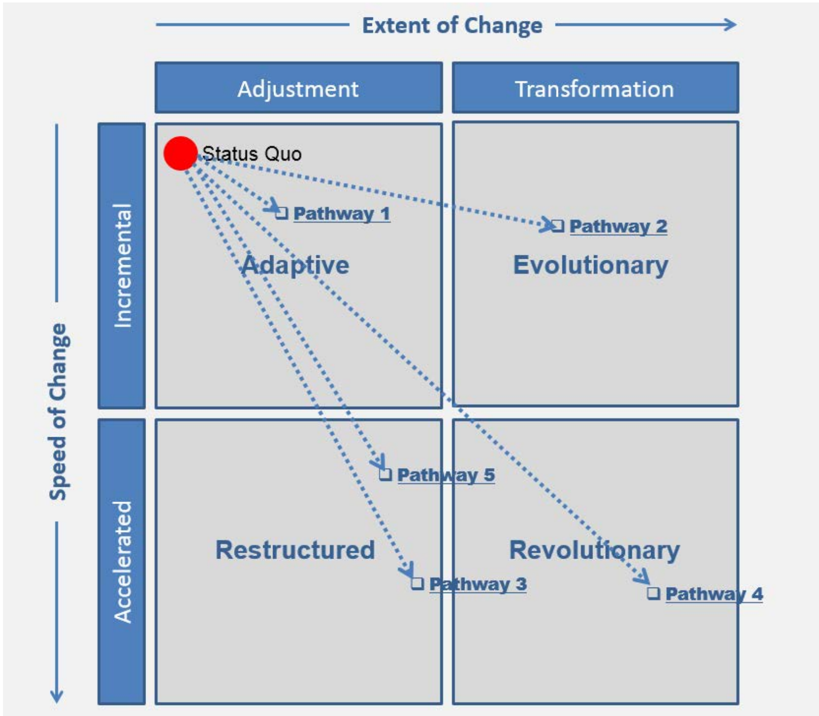


**Figure 1. Pathways toward power system reform in Mexico**

Source: Adapted from Zinaman et al. (2015)

The ultimate goal of all the pathways is to achieve power system transformation, but the pathways differ in how that transition looks in the early stages of the transformation. For a description of the ESTA Roadmap (2015) policies encompassed in each pathway, see the report *The Smart Grid Regulatory Framework for Mexico* (ESTA 2014).

# 3 Optimal Feasible Pathway

The Optimal Feasible Pathway that was presented to Mexico's Grupo Nacional de Redes Eléctricas Inteligentes represents the middle ground of four potential pathways that were judged to have the highest likelihood of success. The 11 elements comprising the Optimal Feasible pathway (Pathway 5) are:

- Develop and implement smart grid standards
- Fund the completion of "wholesale" smart grid investment and enable retail customer direct investment
- Plan and implement selective smart meter installation
- Enable third-party role in smart grid services
- Establish shared renewable programs
- Allow retail customer aggregation
- Streamline distributed generation (DG) interconnection processes
- Adopt innovative tariffs (commercial self-provision, virtual net metering on utility-built renewable projects) and rate design options
- Improve regulation, adding performance incentives that emphasize reliability
- Undertake consumer education on energy use
- Characterize system losses and seek to reduce technical and non-technical losses.

Each of these activities is discussed in greater detail below.

## 3.1 Develop and Implement Smart Grid Standards

Every country that has developed a smart grid has begun with the development of standards. There are at least four reasons why standards development is important: (1) utilities can be assured that devices have the capabilities that meet their needs; (2) utilities and consumers are assured that all smart grid devices are interoperable; (3) with the publication of standards, the vendor industry receives guidance on where Mexico is headed with smart grid investment; and (4) publicly stated and enforced standards will increase competition in Mexico for smart grid devices and services.

In the United States, responsibility for developing smart grid interoperability standards was given to the National Institute for Standards and Technology (NIST). The process for developing standards took more than 2 years and involved stakeholders from all parts of the U.S. power sector. The result of that work is a comprehensive set of standards that addresses every aspect of smart grid interoperability.[2]

Mexico does not need to reinvent the wheel by developing smart grid standards from scratch. Instead, SENER, CFE, and CENACE can adopt existing international smart grid standards. As part of that process, we encourage Mexico to examine the standards that have been developed by the European Union, Canada, Japan, China, the United States, and other countries. The ESTA Roadmap contains a useful discussion on the importance of developing smart grid standards

[2] The U.S. smart grid standards are available on the International Electrotechnical Commission website http://www.iec.ch/.

based on details from various international smart grid standards. The ESTA Roadmap (ESTA 2014, 4-18 [English version]) concludes with the recommendation that:

> Recommendation CFE-2: CRE should require that all power sector actors, in collaboration with the industry and with existing standards bodies, adopt and publish standards for Smart Grid, building on successful experiences in other countries.

Standards development should involve and rely on a consortium of industry participants, coordinated by a neutral entity such as SENER, CRE, Instituto Nacional de Electricidad y Energías Límpias, Normas Oficiales Mexicanas, or the Asociación de Normalización y Certificación, A.C.

## 3.2 Fund the Completion of *Wholesale* Smart Grid Investment

We refer to grid-facing investments in smart grid as ***wholesale*** smart grid investments. In contrast, those investments that enable primarily customer-facing applications are called ***retail*** smart grid investments. CFE and CENACE have made a start with wholesale smart grid investments in the transmission grid and the distribution grid. There appear to be budgetary limitations on the full use of these investments even though most are likely to improve reliability by limiting outages and their duration.

CENACE has installed a significant number of phasor measurement units (PMUs), also known as “synchrophasers.” These devices can provide transmission system operators with data that can be used in real-time operations of the transmission grid, as well as offline analysis to assist with planning and post-mortem analysis of faults. CENACE is apparently using PMU data for the post-mortem analysis, but, because of budgetary limitations, has not begun to use PMUs for real-time operations or for planning.

SENER’s policy leadership in Mexico should be designed to enable and induce CENACE to: (1) install additional PMUs as required; (2) develop the requisite supporting architecture (communications, data storage, decision-making software); and (3) develop a plan to make full use of the data provided by the PMUs in real-time operations and in transmission planning.

SENER’s policy should also induce CENACE to explore additional transmission smart grid investments, including the “smart wire” technologies that promise to transform the transmission grid into a flexible network capable of adjusting power flows and line loadings in an automated fashion.

CFE has begun to make wholesale smart grid investments in the distribution system. SENER policy leadership should enable and induce CFE to complete installations of the key components of wholesale distribution smart grid investment. These include the: (1) selective installation of intelligent customer meters (discussed further below), (2) installation of equipment health sensors at secondary transformers, (3) intelligent fault detection devices, and (4) automated feeder switches.

The applications of these devices are numerous and will serve both wholesale and retail smart grid functions. The primary effects of the use of these applications are a reduction in the number of outages, number of customers affected, and duration of outages. These devices will also lower operating costs by enabling the utility to monitor the health (temperature and loading) of transformers. Finally, smart meters can enable CFE to improve efforts toward voltage optimization.

The focus of SENER's policy leadership should be on prioritizing the timing and location of the installation of these devices, assisting CFE and CENACE in obtaining needed investment capital, and developing staff expertise at CFE and CENACE to maximize the value of these smart grid devices.

## 3.3 Plan and Implement Selective Smart Meter Installation

The popular view equates the smart grid with smart meters. Of course, smart grid refers to more than smart meters. But smart meters (advanced meter infrastructure [AMI]) will be needed for many retail smart grid applications and for some wholesale smart grid applications.

In Mexico and many other countries, there is a wide spectrum of retail customers with a wide range of monthly electricity use. CRE can exploit the variety of customer types by selectively targeting the installation of smart meters. Advanced meter functionalities include customer-facing functionalities and grid-facing functionalities (Raab Associates, Ltd. & Synapse Energy Economic, Inc. 2013). Targeting the deployment of meters should consider both.

Customer-facing functionalities relative to most AMI meters in use today include:

- Drive-by meter reading
- Registering time-of-use consumption and production
- Registering time interval consumption
- Daily read capability
- Real-time read capability
- Ability of the customer or grid operator to communicate with the meter
- Ability of the meter to communicate with devices in the home (e.g., the appliances or thermostat).

These customer-facing capabilities may not be useful to very small customers with few appliances. For that reason, a screen for determining which customers should be migrated to AMI should consider which customers could substantially affect their use by having access to these capabilities. In addition, internet-based controls (like the Nest thermostat) may be sufficient to enable customers to affect their pattern of consumption. Thus, initial deployment of AMI should be focused on larger customers for whom internet-based controls provide too little functionality to meaningfully affect consumption. For those customers who wish to participate in load control programs that will be dispatched by a third party, the distribution utility, or the grid operator in support of system reliability, AMI can be useful for ensuring performance validation based on detailed historical data.

From a grid operator's perspective, the grid-facing functionalities are more important for targeting which customers have AMI capability first. Grid-facing meter capabilities include:

- Remote service connection and disconnection switching
- Power quality reading

- Outage identification and restoration notification
- Generation of distribution system-level data for planning purposes.

The distribution utility and the grid operator are most likely to be able to use these functionalities to gain visibility into areas of the grid that are prone to outages and into specific circuits where customers have large variable loads or have onsite distributed generation (DG).

Taken together, the customer-facing and grid-facing functionalities indicate a path toward prioritizing AMI deployment to improve reliability and keep system costs down. AMI should first be deployed to customers who:

- Are located in service areas of the grid that are vulnerable to outages
- Have a large enough load that the information can be used to meaningfully affect time and quantity of consumption
- Are intending to participate in dispatchable load control programs or tariffs where AMI quality information is superior for validation relative to internet-based controls
- Are intending to or already have onsite DG and/or large variable loads so that operator visibility into the customer side of the meter is important
- Are located in the service area of a priority substation where improved control of flows on the customer side of the substation is important for maintaining grid reliability or restoring outages.

Universal deployment of AMI to all customers without considering the benefits of AMI functionalities will be expensive and could adversely affect the electricity bills of customers who cannot make use of the functionalities. Deployment should be focused on those customers and places in the grid where customer and grid-facing functionalities can have a favorable impact on reliability, resiliency, and customer bills.

Finally, the deployment of AMI devices to selected commercial and residential customers should be integrated with the movement toward smarter rate structures. The ESTA Roadmap (2014, 4-36 [English version]) recommends that Mexico consider applying mandatory time-of-use tariffs to residential customers with the largest electrical use.

## 3.4 Enable Third-Party Role in Smart Grid Services

Consumers will soon be introduced to smart grid ***apps*** provided by third-party vendors. These may entail hardware (e.g., thermostats or motion sensors) but might also be mainly software (e.g., applications to analyze customer usage data). For many customers these apps will provide a level of control that allows them to affect the time and quantity of consumption without having AMI metering capability. Allowing third parties to sell these services directly to customers reduces the need for distribution utility investment and thus limits the commitment of ratepayer funds to supporting deployment. Distribution utility demand response programs or tariffs can be paired with deployment of the third-party apps to establish a compensation stream for customers that reflects the contribution of participating customers on mitigating system loads. A more favorable system load shape benefits all customers, and thus, appropriate compensation from all customers to those who choose to invest and participate in these tariffs is justified.

In the longer term, as third-party aggregators emerge, these apps can be marketed by aggregators as part of an overall retail customer service package. The aggregator recovers the value created by the app by beneficially participating in the wholesale market, the participating customer benefits from having a preferred tariff offered by a competitive provider, and all customers benefit by having low-cost, demand-side resources being bid into wholesale markets.

Government policy should enable and encourage new, third-party providers to enter the market in Mexico.

## 3.5 Establish Shared Renewable Programs

One of the more promising ways in which consumers can gain access to renewable energy is through shared renewable installations. Instead of owning a rooftop solar system, for example, a business or residential customer can purchase or lease a share of a large solar array, which is a centralized solar facility shared by individual customers who receive credits on their electricity bill for the power produced in proportion to the number of shares they have purchased or leased. Many customers cannot have a solar system because of unsuitable roofs, shade from trees, or use so low that a very small system would not be economical.

Such “community solar” projects (also called “solar gardens”) can be connected to the utility system and located on suitable land proximate to the distribution system where subscribing customers take their energy, with output apportioned to customers that subscribe to the project. The end-use customers might own or lease the panels, similar to arrangements with rooftop solar developers, and they are typically compensated on a net energy metering or value of solar basis. To make the projects financially feasible, developers may require participants to sign long-term contracts for the output of their share of the project. Because the power delivery is not connected to a physical address, customers can retain their share of a community solar project if they move within the service territory of the utility.

Community solar gardens might range in size from 50 kilowatts to 10 megawatts. By strategically siting these community solar projects, the utility can improve distribution system operations, locating them on substation feeders with available capacity. In some circumstances, community solar projects can reduce congestion on the distribution grid.

The utility essentially wheels the output of the community solar project to the customers who participate in the project. The utility also performs the function of a financial clearinghouse, crediting the customers for their share of the output through virtual net metering.

In Mexico, community solar projects could be owned and operated by CFE or by independent solar developers. In the United States, the community solar market is growing very rapidly, encouraged by consumer demand and incentivized by federal tax policy.[3]

To promote community solar projects in Mexico, SENER should champion policies that:

- Clarify the legal authority of community solar projects to operate in Mexico

[3] See: http://www.utilitydive.com/news/how-the-utility-role-in-community-solar-is-evolving-as-the-sector-matures/410711/.

- Clarify the relationship of CFE, the community solar developer, and the end-use customer, who will remain a customer of CFE while purchasing some of its energy from the community solar project
- Direct CFE to file tariffs with CRE, establishing the price paid to community solar projects and the bill credit available to the end-use customer who participates in a project
- Ensure that CFE adopts suitable interconnection policies for community solar developers
- Require CFE to publish a publicly available interconnect queue and details about the suitability of its substations to host a community solar development.

Finally, shared solar renewable systems with other renewable technologies, such as wind generation, should also be considered.

## 3.6 Allow Retail Customer Aggregation

As a "wires" company, CFE should expect to serve an increasingly diverse set of consumer loads. Some customers will choose to control their consumption as they gain access to AMI-based information, AMI-based load control, or internet-based load control devices. Some customers will choose to install DG, participate in shared renewable programs, install storage, or purchase an electric vehicle. The distribution utilities and CRE will have the challenge of designing tariffs that fairly compensate these customers while ensuring these customers are not unfairly paying for their share of the grid. In the near term, the emergence of diverse customers will require tariff innovation. In the longer term, the emergence of third-party aggregators will reduce the need for distribution utility tariffs. Third-party aggregators will be able to offer customers a package where customers choose the devices, services, rate designs, and tariff terms based on a competitive evaluation.

While distribution utility tariffs will persist in some measure, the emergence of competitive retail providers who can aggregate customers and independently engage in wholesale transactions on behalf of their customers will give customers more choices and spur market-based innovation. Customers will have the ability to choose services ranging from current service options to services that include DG ownership, storage ownership, load controls, shared renewable ownership, or even participation in a microgrid based on the value proposition presented by competitive and incumbent retail providers.

Setting the stage for innovation in retail services requires that customers begin to have access to retail customer aggregation options.

## 3.7 Streamline DG Interconnection Processes

One of the most important factors in encouraging DG is the adoption of a good interconnection process. The IEEE interconnection standard (IEEE 1547) is evolving, and the Smart Inverter Working Group in California is leading the IEEE standard with respect to incorporating advanced inverter capabilities into its Rule 21 interconnection standard. It is important to recognize both standards are good models, but both continue to evolve to catch up with improving technologies and system communications and controls.

Implementing a best practice interconnection standard includes several factors, including:

- Setting appropriate interconnection fees
- Streamlining all interconnections by adopting appropriate decision tree screens
- Adopting streamlined interconnection for larger DG units that are not covered by net metering
- Adopting standardized technical requirements
- Providing standardized, simplified application forms and contracts
- Defining a process to address disputes
- Allowing DG systems to interconnect to both radial and network grids.

Consideration for location-specific situations on the grid must be reflected in a streamlined interconnection process. A good interconnection standard should recognize when no system impact is anticipated, and thus, fast interconnection is possible. Advanced inverter capabilities can make fast interconnection possible in some locations where improved visibility and control enabled by the advanced inverter effectively mitigate system impact concerns. In this way, streamlined interconnection can be extended to more projects if advanced inverter capabilities are present.

Figure 2 (Sheaffer and Schwartz 2011) provides an example of an interconnection decision tree screen that provides the decision points in a screening process to determine the level of interconnection review required. Simple interconnections below a predetermined size threshold, 11 kilovolt-amps in the example shown, should be executed on a very short timeframe. While larger systems receive some additional scrutiny, an effort should be made to streamline the interconnection review and approval process for all sizes of DG systems.

Finally, we consider the importance of allowing interconnection to radial and network grids. Early DG interconnection policies in the United States limited interconnection of larger systems to radial grids, but interconnection of DG to networks is becoming increasingly important. Interconnection in network or local distribution networks presents protection and grid operational challenges to address inadvertent back feed into the local grid that can cause safety concerns and failure to serve loads. However, with careful operational planning and system protection review, DG can be accommodated, and IEEE 1547.6 was drafted to establish the proper review procedure.

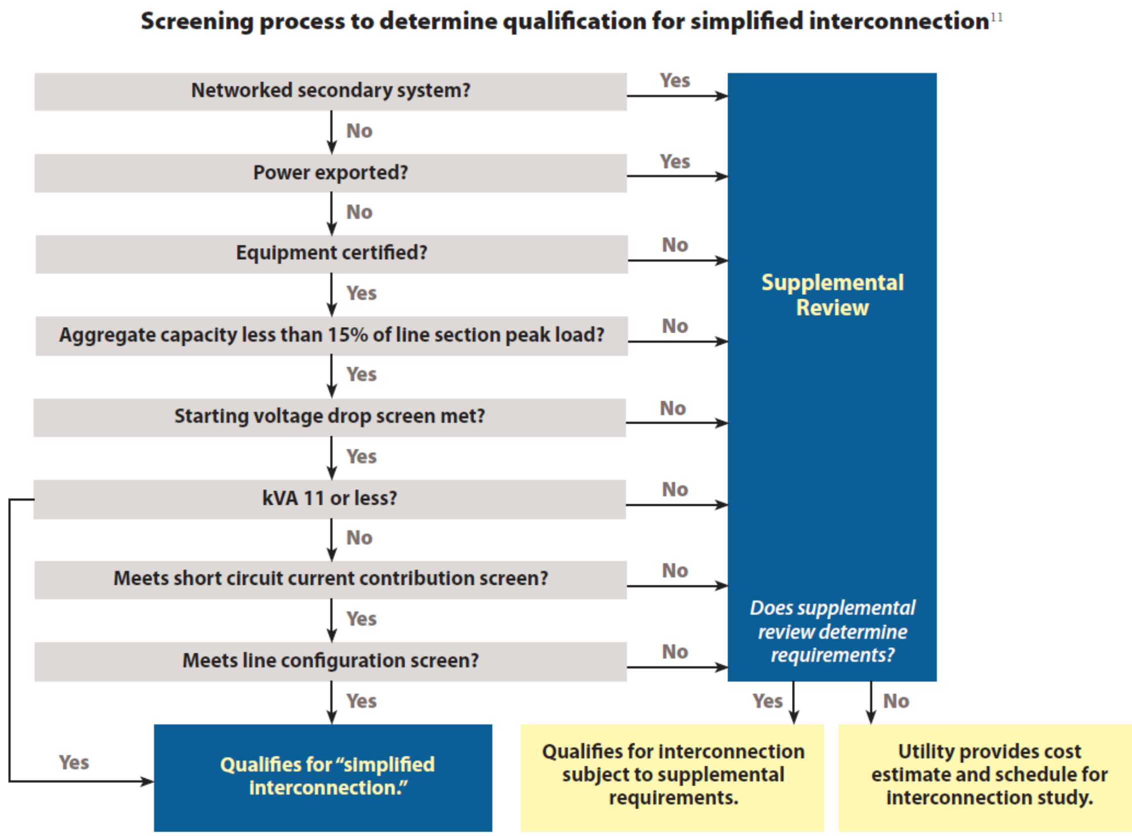


**Figure 2. A sample screening process decision tree**

Source: Schaeffer and Schwarz (2011), Figure 2, page 4.

## 3.8 Adopt Innovative Tariffs and Rate Design Options

Rate designs and tariffs must evolve because technology is changing, and Mexico's power sector reforms are changing the nature of the customer-utility relationship. Technological change in DG and storage technologies is improving the economic viability of customer-side resources. Further, technological change in information, communications, and electric control systems is enabling interactions between electricity end users and electricity service providers to be more temporally and geographically granular. These technological changes and the Mexican power sector reform are acting together to enable two-way provision of energy and services, and the rates and tariffs in place today do not adequately recognize that two-way relationship. Establishing fair rates and enacting fair tariffs begin with establishing the sources of value that resources and services provide.

The first step in establishing fair rates and tariffs is to undertake a comprehensive valuation that identifies the sources of costs and benefits of the full range of distributed energy resources, including a broad range of energy storage technologies, DG, and energy efficiency. This exercise is dealt with in detail in "Designing Distributed Generation in Mexico" (Linvill and Brutkoski 2017). Understanding the value proposition from the adopting customer, non-adopting customer, utility, and social perspective is essential in establishing a rate design and tariff design. Examples of tariffs that can be used as a starting point in designing innovative tariffs include net energy metering, virtual net metering, feed-in tariffs, and value of solar tariffs.

Fair tariffs are founded upon fair rate design. The rate design principles that lead to fair valuation of distributed energy resources are:

> **Principle 1:** A customer should be able to connect to the grid by paying no more than the cost of connecting to the grid.
>
> **Principle 2:** Customers should pay for grid services and power supply in proportion to how much they use these services and how much power they consume.
>
> **Principle 3:** Customers who supply power to the grid should be fairly compensated for the full value of the power they supply.

A corollary to these principles is that people should pay and be paid according to locational and temporal conditions when possible. There will be a time where locational and temporal values will be available, but until that time, these principles indicate an inclining block volumetric rate with a small customer charge and possibly a small demand charge. As the quality of information improves, time-of-use rates and possibly dynamic pricing can be incorporated into the tariff (Lazar and Gonzalez 2015).

If revenues collected are inadequate to ensure reliable utility service, then a minimum bill or demand charge approach should be considered to stabilize the utility service. Fixed customer charge increases promote perverse economic incentives and lead to overconsumption.

For commercial, industrial, public sector, and residential aggregators who choose to buy and sell in wholesale markets as that opportunity becomes available, most will continue to have a tariff with the utility for some utility services. The most common tariff is called a standby or partial requirements services tariff. The tariff terms should be fair and, to the extent that compensation under the tariff is established by regulation rather than a market, the cost paid to the utility and system operator for energy and services procured and the compensation paid to the customer for energy and services provided should be fair. The principles of fairness should be consistent with Principles 1–3 above.

All the benefits of a smart grid to customers and to the grid will depend on the motivation of customers to respond to prices of electricity, whether that happens through administered tariffs or direct interaction with wholesale markets. The current rate structure, which is not time sensitive or location sensitive, is unlikely to produce changes in consumer behavior, even if smart grid devices are available. Therefore, distribution utilities should introduce time-sensitive and possibly location-sensitive tariffs to the largest residential customers as those customers are provided with smart meters. Distribution utilities should also introduce new tariffs that facilitate commercial, industrial, and public-sector wholesale market procurement.

One option in residential rate design would be to make the time- and location-specific rate and tariff structure mandatory for the residential customers who use the largest amount of electricity. These customers are likely to be wealthier and more able to participate in smart grid offerings from utilities and third parties. Further, the largest residential customers use a relatively greater amount of the total electricity consumed by the residential class. Although statistics about the distribution of monthly residential use in Mexico are not available, similar data in the United States suggest that the top 20% of residential customers likely consume about 50% of the power in the residential sector. Targeting those customers with time-sensitive pricing will address a large fraction of the total kilowatt-hours sold and provide a ready market for smart grid vendors. These customers who use relatively more power are obviously where AMI investments will prove to be most cost effective.

## 3.9 Improve Regulation, Adding Performance Incentives That Emphasize Reliability

Everyone knows that the electric power sector is changing rapidly—this is nowhere more evident than in Mexico, following passage of the *Reforma Energética*. But while the industry is changing rapidly, regulation may not be keeping pace. Today, utilities are being asked to serve many functions that were not historically required of them, including inducing consumers to use electricity more efficiently, reducing and eventually eliminating carbon dioxide emissions, and integrating new sources of electricity—both renewable and distributed. Despite these broad societal goals, traditional regulation often does not reward utilities for achieving those goals.

One obvious area of focus for regulatory incentives is electric grid reliability. While a given level of reliability may have been adequate in the past, that same level might not be sufficient today. The requirements of today's digital economy mean that outages and poor power quality can deprive customers of essential services, including safety, communications, and commerce. Few modern businesses can tolerate poor reliability and power quality, given their reliance on IT systems and communications.

Insufficient reliability can have an environmental effect as well. If customers must turn to backup generation to supplement utility service, they will likely be using a fuel source that is much more harmful to the environment compared to utility generation. Of course, fuel used in backup generation will also be much more expensive than utility-supplied power.

Modern regulation should be improved to incorporate performance standards for utilities. Regulators should adopt performance standards and hold utilities accountable with a system of rewards or penalties. There is no more obvious candidate for incentive regulation than the utilities' performances on grid reliability.

In designing performance measures, regulators are faced with two basic tasks: (1) selecting performance metrics with performance targets and (2) designing a system of financial incentives. Regarding the selection of metrics, experts (Whited et al. 2015) counsel that the appropriate design principles require the metrics to be:

- Tied to the policy goal
- Clearly defined
- Able to be quantified using reasonably available data
- Sufficiently objective and free from external influences
- Easily interpreted
- Easily verified.

In designing a system of financial incentives for utilities, it is advised that these design principles be followed (Whited et al. 2015):

- Consider the value of symmetrical versus asymmetrical incentives
- Ensure that any incentive formula is consistent with the desired outcome
- Ensure a reasonable magnitude for the incentive
- Tie incentive formula to actions within the control of utilities
- Allow incentives to evolve.

It is probably more straightforward for regulators to create financial incentives for regulated investor-owned utilities, in contrast to publicly owned utilities like CFE and CENACE. Regulators in Mexico must adapt financial incentives to be meaningful in this situation. One possible area to explore is requiring utilities to base changes in executive compensation on performance against the performance measures.

## 3.10 Undertake Consumer Education on Energy Use

The success of the modern electric grid will depend in part on the active participation of consumers, or of agents on their behalf, such as aggregators or third-party smart grid providers. In particular, accomplishing Mexico's energy goals will require a consumer base that is more informed about energy use and its connection to the environment. Consumer education can also be used to help achieve less lofty goals, such as a reduction in non-technical losses caused by theft of electricity.

There are several channels through which SENER, CRE, CFE, and CENACE might act to build customer knowledge about energy use:

- Use by CFE of customer engagement services such as Opower or Tendril; comparison of usage to peers is interesting to customers and familiarizes them with their own electric profile
- A public information campaign focusing on a well-defined message; for example, a campaign to brand the diversion of electricity as socially unacceptable and harmful to others
- A customer web portal at which customers could, for example, see their bill, pay their bill, estimate the benefits of solar, and learn energy efficiency techniques
- A speakers' bureau from SENER, CRE, CFE, and CENACE available to present at community meetings
- Use of bill inserts or other customer contact opportunities (point of sale for pre-paid)
- Greater use of social media to engage customers; the agencies should engage an expert to ramp up their presence on all social media platforms and convey energy-related messages in a way that is appealing to younger people.

## 3.11 Characterize System Losses and Seek to Reduce Technical and Non-Technical Losses

Worldwide energy losses in the transmission and distribution systems of electric utilities reduce the efficiency of providing electricity, cause more pollution, and drive up prices to consumers. Reducing losses can be a very challenging undertaking by utility managers and requires an integrated approach that includes improved measurement, equipment installation, employee training, customer education, and the utility management's commitment to a long-term effort.

Smart grid investments can help to reduce both technical losses (due to inappropriately loaded or improperly maintained facilities) and non-technical losses (due mainly to theft of electricity from meter tampering and irregular network connections).

Smart grid investments for reduction of technical losses include:

- Telemetry from PMUs that improve situational awareness for the transmission system, allowing operators to reduce inefficient line loadings
- “Smart wire” technologies to improve transmission system operations
- Telemetry about the condition of distribution equipment (e.g., overloaded transformers)
- Substation monitoring and automation
- Data from meters and transformers, permitting voltage optimization on distribution circuits
- Improved measurement to isolate causes of technical losses
- Time-sensitive pricing to reduce peak loads and thus losses.

Smart grid investments for reduction of non-technical losses include:

- Improved metering capacity, reducing inaccurate metering that creates commercial losses
- Installation of remote meter reading systems
- Reduced meter tampering by locating secure AMI meters near distribution transformers
- Consumer feedback about usage patterns.

CFE is in the process of installing hundreds of thousands of AMI devices in selected districts in Mexico. Requests for proposals for the Reduction of Energy Distribution Losses program resulted in awards to several vendors, including Silver Springs Networks, Siemens, Eléctricas de Medellín Ingeniería y Servicios, and Edemtec. SENER must ensure through its policies that the capabilities of these new meters are consistent with the longer-term vision of grid modernization.

In addition to hardware solutions, this Optimal Feasible pathway identifies other activities that can lead to lower non-technical losses. First, in the previous section, we stressed the need for customer education about theft of utility service. Public service communications that emphasize that theft of electricity costs everyone else money could help develop an ethic of bill payment and turn public opinion against the theft of electricity by others. Second, we have stressed the need to begin incorporating incentives (positive and negative) into the regulation of utilities in Mexico. It may be useful to make loss reduction a performance indicator in any system of incentive regulation for the distribution utilities.

# 4 Policy Focus: Tracking How Optimal Feasible Smart Grid Implementation Achieves Reliability Improvement

The Optimal Feasible pathway identifies 11 smart grid elements that should be implemented first to modernize the grid. Success in implementing these first elements will be critical in maintaining public support for the ESTA Roadmap vision during the early years and for fully achieving the goals of Mexico's constitutional reform, the *Reforma Energética*, over time (ESTA 2004). Thus, connecting these elements to popular policy goals and demonstrating that progress is being made in achieving these popular goals is essential.

The ESTA Roadmap recognized several cross-cutting goals for the *Reforma Energética*, and a number of these goals are candidates for demonstrating the impact of these initial smart grid priorities. A few representative goals include:

- Reliability improvement
- Cost containment
- Customer engagement
- Clean energy growth
- Universal service
- Economic development.

Each of the 11 Optimal Feasible smart grid elements described in Section 3 has the potential to advance each of these goals. Each goal is essentially a different lens through which one may assess the progress toward achieving the benefits of the smart grid elements, so there is value in tracking progress toward all six goals (and perhaps a few others). However, perhaps no goal is more important in building consensus support for smart grid implementation than reliability improvement. Here we use the goal of reliability improvement and its expected benefits as an example to illustrate how smart grid implementation effectiveness should be tracked and measured relative to this goal.

The ESTA Roadmap summarized a number of benefits for reliability improvement that should be observed with wise smart grid investment. There are many benefits, but a few that are amenable to assessing the effectiveness of the Optimal Feasible Pathway elements include the following (ESTA 2014, 3-9):

- Improved asset utilization
- Transmission and distribution capital savings
- Transmission and distribution operations and maintenance savings
- Theft reduction
- Loss reduction
- Cost savings
- Reduced power interruptions
- Increased power quality
- Increased energy security.

The Optimal Feasible smart grid policies can be grouped into three types of elements: those that implement market or operational reforms (Reforms); those that engage customers in helping to improve electricity sector performance (Engagement); and those that require utility, government, or third-party investment (Investment). The Optimal Feasible elements can thus be grouped as shown in Table 2.

**Table 2. Optimal Feasible Smart Grid Elements for Implementation[4]**

| Reforms |
|---|
| 1. Develop and implement smart grid standards |
| 2. Streamline DG interconnection processes |
| 3. Enable third-party role in smart grid services |
| 4. Improve regulation, adding performance incentives that emphasize reliability |
| 5. Characterize system losses and seek to reduce technical and non-technical losses |
| **Engagement** |
| 1. Adopt innovative tariffs and rate design options |
| 2. Establish shared renewable programs |
| 3. Undertake consumer education on energy use |
| 4. Allow retail customer aggregation |
| 5. Enable wholesale and retail customer direct investment |
| **Investment** |
| 1. Fund the completion of "wholesale" smart grid investment and enable retail customer direct investment |
| 2. Plan and implement selective smart meter installation |
| 3. Adopt innovative tariffs and rate design options (that facilitate wholesale and retail customer investments) |
| 4. Establish shared renewables programs (that induce customer investment) |

With respect to those elements that seek to reform practices, markets, and operations (the Reform category in Table 2), assessing the impact of these reforms comes down to assessing whether the reforms are implemented in a timely manner, assessing whether the reforms have had an impact, and attempting to measure whether those impacts have been positive or negative. The reforms will have overlapping benefits, so precise allocation of benefits to specific reforms will not always be possible; one would at least like to see a positive correlation of the reforms with specific benefits over time.

With respect to those elements that seek to engage customers and the private sector (the Engagement category in Table 2), assessing the impact of the engagement elements comes down to tracking how many customers become engaged in tariffs, programs, and investments that produce system reliability and resiliency benefits; how large the net system reliability and resiliency benefits from customer engagement are; how many third parties become active in

[4] Some activities affect both engaging customers and inducing private investment, so some policies are listed twice in Table 2, giving the appearance of 14 policies for implementation when there are only 11.

providing services that affect system reliability and resiliency benefits; and how large the system reliability and resiliency benefits created by third parties are.

With respect to elements that seek to elicit investment (the Investment category in Table 2), assessing the impact of private investment on reliability and resiliency becomes a matter of tracking the source and magnitude of the investments, computing the magnitude of ratepayer funds saved by having private funds take on investment, and measuring the reliability and resiliency benefits of the private investment over time.

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