Smart metering

in Latin America and the Caribbean

Regulatory recommendations to encourage the deployment of smart metering appropriate to the needs of individual countries

BID

Smart metering in Latin America and the Caribbean

Regulatory recommendations to encourage the deployment of smart metering appropriate to the needs of individual countries

Editors

José Luis Irigoyen
Juan Carlos Cárdenas
Eric Daza
Yuri Daltro
Michelle Hallack

Authors

Oliverio Álvarez Alonso
Noé Augusto Afonso Pérez
Alberto González-Salas Mosquera
Estefanía Hernández Raya

March, 2023

Acknowledgements

This report is part of the knowledge agenda developed by the Energy Division of the Inter-American Development which aims to develop new knowledge products and technical assistance programs for Latin American and the Caribbean (LAC) region. The produced knowledge products intend to inform, guide, and offer a menu of policy recommendations to policymakers, and active participants in the energy markets, including consumers, utilities, and regulators. Specifically, the objective of this report is to identify the current state of the deployment of smart metering in the LAC region to make certain recommendations for LAC energy regulators and encourage their deployment in a manner which matches each country's specific needs.

The report was prepared under the overall guidance of Marcelino Madrigal (Energy Division Chief). The task team leader is Jose Luis Irigoyen. The main authors of the report are Oliverio Álvarez, Noé Augusto Afonso, Alberto González-Salas, and Estefanía Hernández from Deloitte. Task team members include Michelle Hallack, Juan Carlos Cárdenas, Eric Daza and Yuri Daltro. The team thanks Lenin Balza and Gabriela Montes from the Inter-American Development Bank and Luis Jesús Sánchez de Tembleque from the Ibero-American Association of Energy Regulatory Entities for their comments and review. The team gratefully acknowledges financial support from the technical cooperations "Observatory of Energy Regulation in Latin America and the Caribbean" (RG-T3315) and "Accelerate digitalization in the energy sector" (RG- T3820").

Index

Graphics

Tables

Illustrations

Acronyms

AMI	Advanced Metering Infrastructure
CAPEX	Capital Expenditure
CBA	Cost-Benefit Analysis
CNE	Comisión Nacional de Energía de Chile
CRE	Commission de Régulation de l'Énergie, France
DSO	Distribution System Operator
EV	Electric Vehicle
LAC	Latin America and the Caribbean
MMCS	Metering, Monitoring and Control Systems
SM	Smart Metering
Ofgem	Office of Gas & Electricity Markets, UK
OPEX	Operating Expediture
PUCT	Public Utility Commission of Texas
TSO	Transmission System Operator
TWh	Terawatts hour
Unts	Units
USA	United States of America
USD	United States Dollar
WAN	Wide Area Network

Executive Summary

The objective of this report is to identify the current state of the deployment of smart metering (SM) in the Latin America and the Caribbean (LAC) region, and to make certain recommendations to regional energy regulators to encourage deploying SM in a manner consistent with the specific needs of individual countries and international trends, especially in terms of digitization and decarbonization.

Adopting SM is fundamental in the journey towards the necessary digitization of electrical networks in a new, more decentralized, and decarbonized energy paradigm, which allows immediate, accessible, reliable, and harmonized data to be available for decision-making of main energy agents.

The way the bodies charged with this deployment address SM is especially critical to guarantee its success, not only in terms of deployment, but also in terms of the results obtained and the final transformation of the electricity sector.

This document identifies **some key issues**, listed below, that should typically be considered in the SM decision-making process, especially in its initial deployment, so the process may be undertaken with greater guarantees and permitting to optimize resource allocation.

- **Identifying the needs** to be addressed through SM to design a process that allows the provision of an adequate response.

- Performing a **cost-benefit analysis** of economic feasibility, which considers the entire SM technological ecosystem.

- Defining a **national strategy** which sets objectives and prioritizes key actions for the process.

- Designing a **robust regulatory environment** encouraging the deployment and guaranteeing the materialization of the expected benefits around SM, in an appropriate control environment.

Among other things, SM improves economic efficiencies for the electrical system, optimizes its safety and security, improves supply quality and continuity, creates new markets and business models, further empowering the electricity consumer, makes a real contribution to reducing the economy's carbon footprint and contributes to decarbonization.

In this way, **SM could effectively contribute to the remediation of certain deficiencies in energy systems in some LAC countries** and could contribute to the decarbonization objectives established by many of the region's nations. **However, the deployment of SM in many LAC countries is still incipient or non-existent compared with other regions around the world** (approximately 3.5% in LAC, compared to 30% in the European Union and Australia and over 50% in the US (2020 data).

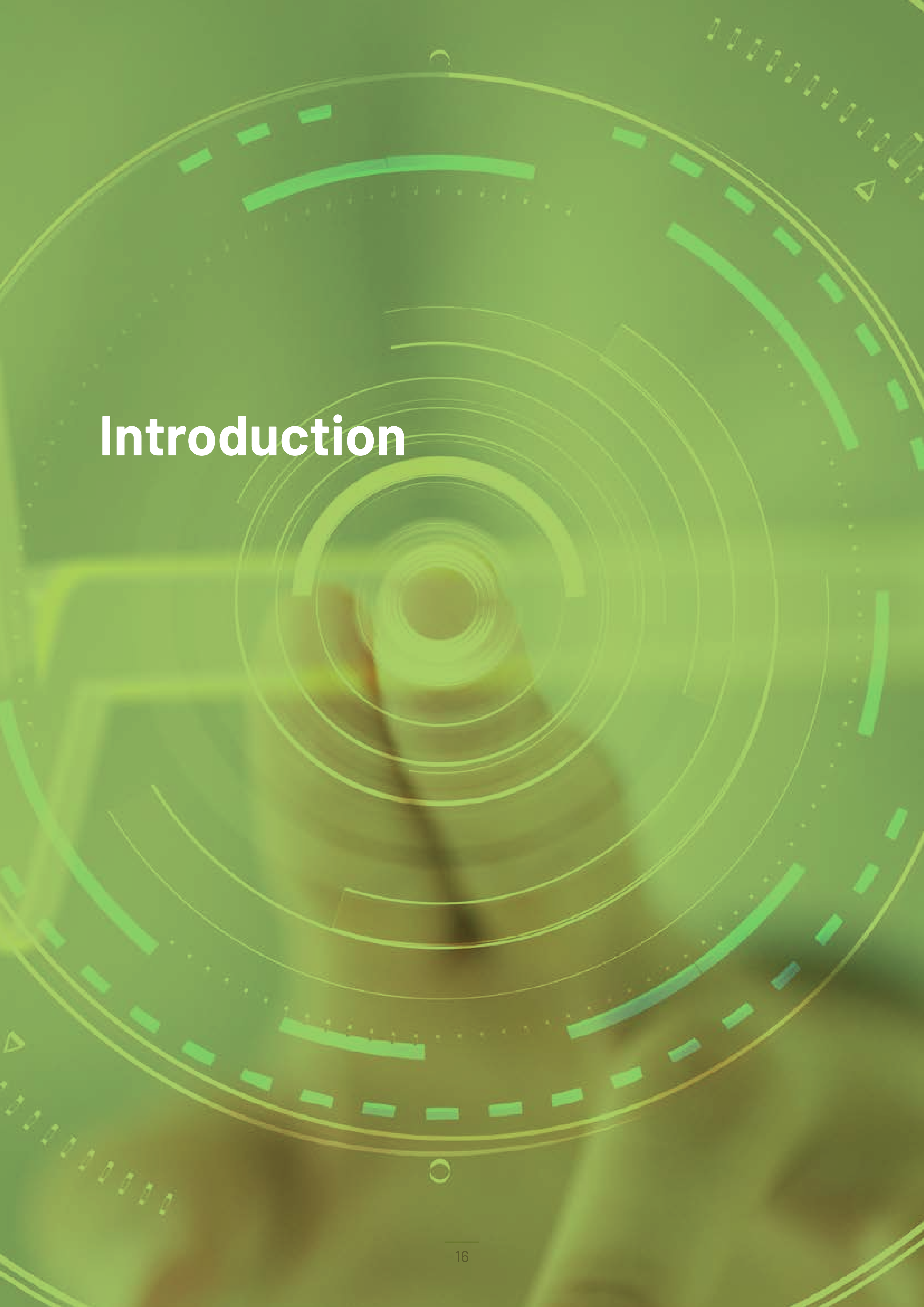
As shown in the document, some LAC countries have started deploying SM. However, the process has been both disordered and inconsistent with best international practices, resulting in inefficiencies and a slow deployment with undesired results.

LAC regulators face a complex challenge, since inadequate regulation can send incorrect signals to the agents involved and give rise to undesirable results and higher costs for the electricity system. Many of the experiences underway may allow us to identify the best regulatory practices, as well as to identify regulatory design errors to be avoided. **This report is intended as a guide for regulators and government institutions presently developing such regulations.**

Objective

The general objective of this report is to identify the current state of the deployment of smart metering (SM) in the Latin American and Caribbean (LAC) region to make certain recommendations for LAC energy regulators and encourage their deployment in a manner which matches each country's specific needs. Consequently, the report identifies some of the best relevant regulatory practices, as well as lessons learned that regulators in LAC countries could use.

This report draws on the latest publicly available information on SM of the 26 IDB borrowing member countries in the LAC region.



Introduction

Fast technology development, sliding digitalization costs and greater societal connectivity are leading to profound transformations throughout the world, including the electricity industry and the agents that shape it.

Expected benefits for electrical systems from adopting new technologies, which allow their greater digitization and connectivity, are very relevant. The potential benefits range from increased energy efficiency, lower costs associated with new investments in networks, optimization of grid operation and maintenance, reduction of electricity losses, improved quality of service and creation of innovative business models, around new ecosystems such as self-consumption, electric mobility, storage or demand management, among others, in addition to contributing significantly to the decarbonization of electricity systems, and empowering consumers to enable their more active involvement in the electricity system.

For this new energy model, electricity generation, transmission and distribution systems must incorporate communication mechanisms and information exchanges (through digitization, decentralization and, where possible, process automation) among all electricity market agents and among the components of the electricity value chain. In brief, **the transition from the traditional electrical system to the new smart grids will allow, in addition to a more efficient generation, transmission and distribution of electricity, to offer new and innovative products and services to the different users of the electrical networks.**

Given this need, it is especially relevant to establish policies and regulations that encourage investment in technologies that allow bringing in new agents and emerging relationships in energy consumption, considering each country's context and particular needs, a scenario that poses major challenges to regulators and government agencies.

The costs associated with the digitization of electrical networks may be small in isolation, but nationwide electrical networks are very extensive. Therefore, digitization must be analyzed as a whole and considering various technologies to collect, treat and its effectively use relevant data for a connected electrical system. Digitization usually results in tangible benefits for the electrical system and society.
But this requires a cross-sectional analysis, not only of the technologies to be implemented, but also of the expected use cases that allow obtaining benefits to mitigate the costs associated with technological deployment. This means we must assess a technology whose main objective is data collection and therefore does not create a direct benefit, needs to evaluate its deployment together with other equivalent developments in aspects related to the treatment, connectivity, or use of such data.

Smart metering (SM) is currently considered by many countries as a fundamental tool on the journey to digitization of electricity networks, including the adoption of new business models in the electricity sector, consumer empowerment and improved relations between industry agents.

SM **enables a more connected, modern, and efficient energy system to support the technologies, services and innovation of the future**. From a technical point of view, consideration should be given to electrical system innovations that allow two-way communication between users and service providers, turning end users into active customers who manage their energy consumption, allowing them to optimize their energy costs, as well as playing an important role in meeting national environmental objectives, among other benefits.

Derived from the above, SM can play an important role in digitizing the traditional grid and facilitating regional or state objectives aimed at expanding, decarbonizing and decentralizing the power grid. However, SM requires regulators and government agencies to create a regulatory framework to foster investment in advanced metering infrastructure and allowing industry players to take advantage of its many expected benefits.

Given the importance of encouraging SM in the electricity sector, many countries have developed or are designing strategies to develop electricity networks amenable to SM. However, their reasons to introduce SM vary across countries.

Some of the main reasons identified worldwide to adopt SM follow:

Illustration 1: Main reasons to adopt SM

Source: Prepared by the authors

Obtaining economic efficiencies for the electrical system associated with operation and maintenance, meter readings and system losses, and planning future investments in networks.

Optimizing the security of the electrical system with greater control over interruptions and supply cuts, derived from the exploitation of historical and real-time data on the state of the electrical network.

Improving the quality and continuity of supply: rapid response on electrical losses (technical and non-technical), cuts, etc.

Allowing to develop new markets and business models, with a greater degree of competition in retail markets and the integration of new agents

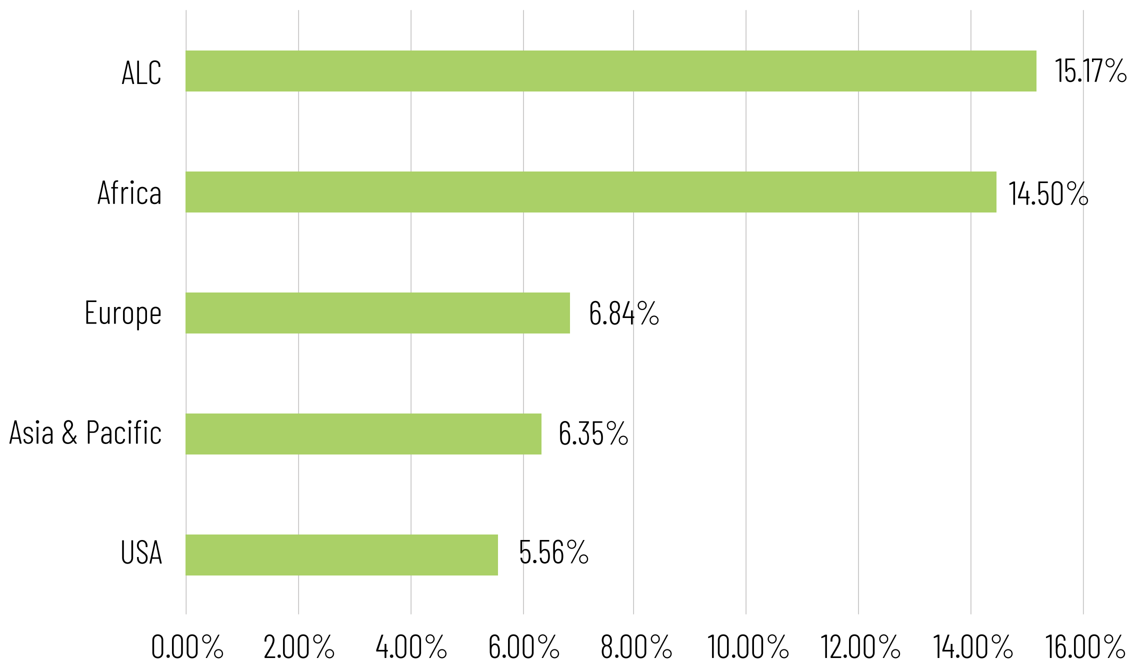
Allowing to empower the consumer with the possibility of developing demand response mechanisms, new flexibility services and the concept of "prosumer"

Contributing to reducing the carbon footprint and decarbonizing the economy by optimizing consumption, reducing electrical losses, and enabling the development of new electrical consumption-production models (self-consumption, electric vehicle, IoT, etc.), as well as the massive integration of renewables, and other implications derived from improvements in the planning and operation of electrical networks.

Some reasons warranting SM development regulatory mechanisms in LAC

In some **LAC countries, adopting SM could provide an effective solution to correct certain deficiencies of their electrical systems,** which typically translate **into energy losses and supply failures.** Comparing percent annual losses derived from the transmission and distribution of electricity between different regions shows the unfavorable situation of many LAC countries, pointing to the need to take measures to encourage the modernization of their electric systems.

Graphic 1: Percentage of generated energy lost through transmission and distribution of electricity
Source: IEA Statistics 2019



As shown in the above graphic, **electricity losses pose a challenge in many LAC countries and are one of the main indicators of inefficiencies of their electrical systems.** In 2019, for example, electrical losses in LAC, in relative terms, reached approximately **15% of the total energy generated, almost triple the rate in the U.S.A. and twice that of other regions such as Europe or Asia and Pacific.**

As has happened in other regions, **the modernization of power grids and their digitization can contribute to reducing this level of losses. Measurement and control technologies,** such as smart meters or decentralized computer systems, allow accelerating the digitization of the electricity sector, contributing to reduced losses through the adoption of systems to allow real-time measurement of users' electricity consumption and detect inefficiencies and losses in specific points of the electrical network in advance. Introducing consumption data analysis systems allows, on the one hand, to identify the critical areas of the network where there are electrical losses, and, on the other, to propose strategies to optimize network configurations to optimize grid use and cut losses by accessing useful information on the points in the network showing deficiencies.

An additional reason to deploy SM in many LAC countries is to pave the way to develop demand-driven **business schemes and models.** Demand response combines new technologies with consumer commitment to become actively involved in the electricity system. However, historically, consumers (especially small consumers) have been considered as price takers or price acceptors, especially in the short term, so to date the penetration of demand-driven business schemes and models has been very limited[1].

It is worthwhile noting that demand **response programs depend on the digitization of each country's electrical system.** Deploying SM makes it possible to encourage behavior changes among both consumers and other players in the electricity sector.

Notwithstanding the foregoing, deployment of SM requires taking a broader vision of existing and future use cases, which must be considered in the design of the deployment. This demands identifying **relevant specific smart meters data collection requirements, and information processing, determining the responsibilities of the agents involved in SM, determining the technical functionalities of the meters themselves, and defining the financing model that will be established to cover the costs associated with deploying SM. This requires promoting a regulatory framework that considers all these elements to foster the adequate deployment of SM that address current and future needs of each country's electrical system.**

The way SM deployment is approached by energy regulators is key to guaranteeing the successful transformation of the electricity sector. In the following illustration, five main stages have been identified that countries typically go through in deploying SM, same that will **determine the final definition of a regulatory environment to foster the successful deployment of smart metering in each country and guarantee its success.**

Some LAC region countries have already begun transforming their electrical systems through various regulatory schemes to encourage and accelerate a successful transformation. However, other countries in the region have followed different strategies with varying degrees of success or have not yet actively addressed such a transformation.

[1] "Empoderando a los consumidores de electricidad por medio de la respuesta a la demanda" (Empowering electricity consumers through demand-driven response). Working document; Inter-American Development Bank (March 2022).

The following illustration shows the main stages toward deploying SM in different countries globally. This staggered approach has enabled numerous countries to obtain measurable results and broad levels of SM deployment. Such a **staggered design to deploy SM may provide a guaranteed process and optimize resource allocation:**

Illustration 2: Design of the optimal process to achieve the deployment of SM in a country

Source: Prepared by the authors

1 | Identify the need

Identification of the fundamental role that the SM can play to encourage the deployment of smart grids and electrification and thereby promote the decarbonization of the countries' economies and/or the fulfillment of national energy objectives.

2 | Perform a cost-benefit analysis (CBA)

Perform a CBA at the national level to measure the profitability deploying SM. This analysis must contain prospective aspects given that the digitization of networks enables new business models in an evolved electrical system.

3 | Prepare a national strategy

Define a national strategy for Smart Grids (or SM, as the case may be) that includes an action plan and objectives to deploy smart meters, so that the incorporation of technological innovation is prioritized, and operational efficiency is guaranteed. Such strategy must consider the country's socioeconomic environment and place consumers at the heart of the electrical system.

4 | Structure an appropriate regulatory environment

Define appropriate regulatory mechanisms to encourage the deployment of SM, including aspects such as remuneration mechanisms, SM functionalities and the definition of the responsibilities of agents and end users as regards SM.

5 | Define a SM control and monitoring system

Define a mechanism to oversee and monitor the deployment carried out in the country, as well as the regulatory environment established around SM.

Structuring an adequate regulatory environment is particularly relevant and critical to encourage SM deployment that provides the expected benefits. Poor design can result in sunk costs for the electrical system and failure to provide benefits for consumers. Therefore, it is advisable that when developing regulation, regulators rely on measurable data and robust information. **A CBA and defining a national smart grid strategy are tools that allow regulators to face these challenges with greater chances of success.**

Electricity sector regulators face a complex challenge, since inadequate regulation can send incorrect signals to the agents involved, giving rise to undesirable results and higher costs for the electricity system. Currently, many **experiences** underway **allow us to identify the best regulatory practices, as well as regulatory design errors to be avoided. This report is intended to serve as a guide for regulators and government organizations involved in regulatory development.** For this reason, it will focus especially on the first four stages, which are key to starting the deployment of national SM systems.

It is true that the technologies associated with SM are very dynamic, so **the greatest challenge for the regulator is to maximize the benefits derived from the deployment of SM.** For this, **it is essential that the regulation process is constantly modernized and adapted** to technological evolution, considering each country's peculiarities.

The need to develop Smart Metering in LAC. Current degree of deployment.

Some needs in LAC requiring an adequate response

Adopting SM in electricity distribution networks in LAC can contribute, as shown in Illustration 1 above, to harvest certain benefits both for the electricity system itself and for society, as for example, improving economic efficiencies for the electrical system by reducing the technical and economic impact caused by high energy losses across grids, a challenge faced by many LAC region countries.

SM could allow benefits to materialize for many of the agents in the value chain of the electricity system, including the consumers themselves, as well as for society since its implementation typically has a favorable impact on decarbonization and reduction of the carbon footprint. The definition of national objectives to reduce emissions[2] would increase the need in the country to have an efficient electrical system and, therefore, would encourage the development of smart electrical networks in the LAC electrical systems and therefore SM.

Some LAC countries have already identified the need to modernize their electricity distribution networks, as well as to gradually adopt SM and various other measures to manage the demand for electricity, and thereby contribute to reducing losses in electrical networks.

[2] The 26 LAC countries covered in this report have signed and ratified the Paris Agreement, and submitted the Nationally Determined Contributions (NDC) documents outlining each country's efforts to reduce national emissions and adapt to the effects. of climate change.
Source: Nationally Determined Contributions Registry | UNFCCC.

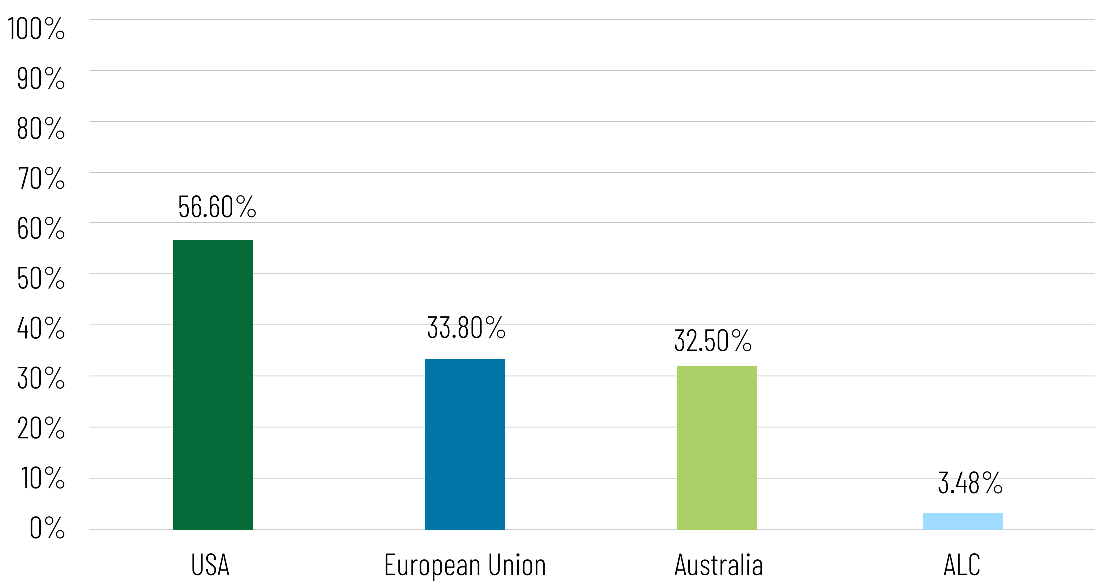
Current degree of SM deployment in LAC

The degree of development of SM in LAC is still relatively low compared to other regions of the world, such as the US, Europe or Australia. However, some of the main agents responsible for the deploying of SM in LAC have already started to put into practice successful SM experiences across the region. In fact, some countries have set concrete objectives for the large-scale deployment of SM and to install house smart meters.

The following graph shows the degree of penetration of SM in different regions and its distance from the LAC region.

Graph 2: Degree of penetration of SM across regions

Source: GPR Economía (2020) for US, the European Union and Australia. Prepared by the authors for LAC



The different degree of SM penetration in the LAC region compared to the US, Europe or Australia is very relevant. In the **US, the European Union and Australia,** the deployment of SM in homes has already exceeded 30%. However, in the LAC region, where deployment is very low, close to 3.5%, according to the public information obtained for this study. In some countries, the transition to SM is negligible or has not begun, to adopt new electronic metering technologies that permit hourly billing.

An important factor that contributes to delaying this deployment of SM in LAC countries is the insufficient investment in infrastructure in the electricity sector, as evidenced by the **significant levels of electricity losses in the distribution network in certain countries,** whether for technical or non-technical reasons, which ultimately translate into higher electricity costs and therefore more expensive electricity rates for consumers, as well as a higher degree of greenhouse gas emissions linked to the production of energy that is not ultimately consumed. **One of the benefits associated with SM is precisely its contribution to reducing both technical and non-technical losses,** in turn contributing to the transition towards a much more efficient electrical system.

In turn, **SM promotes incorporating renewable energies in electrical systems,** by facilitating the distribution of new generation across networks and allowing adopting demand management mechanisms, among other benefits. **Many LAC countries have a high renewable potential or already have a highly renewable electricity generation matrix that must be further strengthened in view of a greater electrification of the economy** as a first stage towards decarbonization.

Many LAC countries have already committed to SM through their various national strategies to build smart grids and/or SM. This, together with the advances in the matter observed in some LAC countries leads us to think in the near future further progress towards SM will take place in the LAC region, permitting **greater control and management of electrical networks,** both at generation and consumption points, which in turn allows a greater contribution to the decarbonization of the electrical systems of these countries.

This conclusion derives from the fact that SM and its associated infrastructure, in addition to allowing hourly rates, adjusting prices to the balance between supply and demand, also allows, through an adequate design, to make readings more reliable, improve fraud detection and reduce other administrative losses. Moreover, it helps to identify network hot spots and prevent technical losses and power outages, improves power grid monitoring, contributes to consumers' load curve analysis, allows two-way readings of energy-generating consumers input into the electrical system, enables interoperability with other devices or other agents in the electrical sector, among many other possibilities.

SM deployment started years ago in several countries, where successful practices and lessons learned have been observed. This report identifies these practices to guide countries that have not started SM deployment or are still in a very early phase.

The application of the successful practices identified in other regions with greater progress in the matter, considering the local needs of each country, **allows for greater guarantees of success** in the process of implementing SM in those countries of the region of LAC that decide to undertake it and the **structuring of an adequate regulatory environment.**

In this sense, to establish a regulatory environment that allows encouraging a successful deployment of SM, **it will be essential to previously carry out a robust CBA** that contemplates all the agents and factors involved.

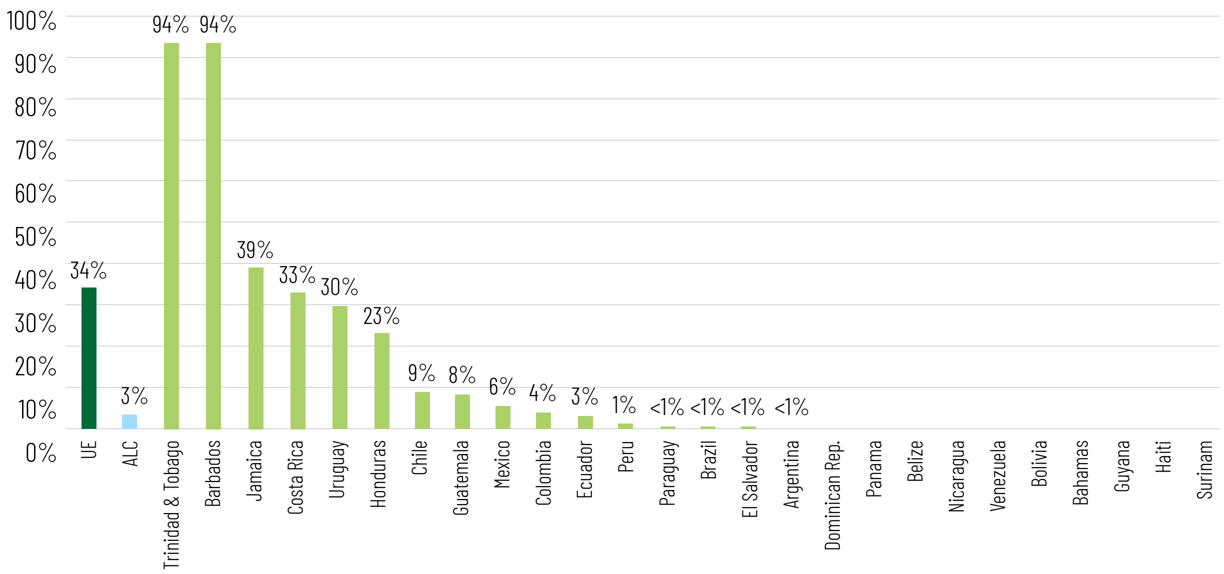
A CBA will allow regulators and government bodies to **assess the technical capacity of their electrical systems, and the expected costs and benefits for users and society of deploying SM.** It will be a key tool to measure the feasibility of SM in each country and, where appropriate, to develop a regulatory environment to foster deployment, contain costs and capture the benefits expected from its deployment.

The degree of success in deploying SM across the 26 nations reviewed to prepare this report varies, with some countries showing extensive development while others show very limited or no deployment. To carry out a comparative analysis, Europe has been chosen as the reference region due to the variable degree of progress of SM in that continent's countries.

As can be seen in graphs 3 and 4 below, SM deployment in **Europe is much higher than in the LAC region, despite, both regions showing very heterogeneous individual country deployments.** Countries belonging to the European Union pursue common objectives regarding SM. CBAs for individual countries point to varying strategies and regulatory designs and outcomes.

Graph 3: Degree of SM deployment in LAC and Europe

Source: Prepared by the authors



If we measure the degree of SM deployment by the number of household smart meters installed among the total number of homes in each country, **Trinidad and Tobago (94%) and Barbados (94%)** show the largest implementation of this type of metering as a result of a

specific investment strategy carried out by the sole power distribution utilities in these two countries aimed at improving the supply and quality of the electrical service.

In turn, Jamaica (39%), Costa Rica (33%) and Uruguay (30%) show deployment degrees close to the average observed in the region. These countries have set **national strategies and objectives** to get SM installed in all residential homes within certain time frames.

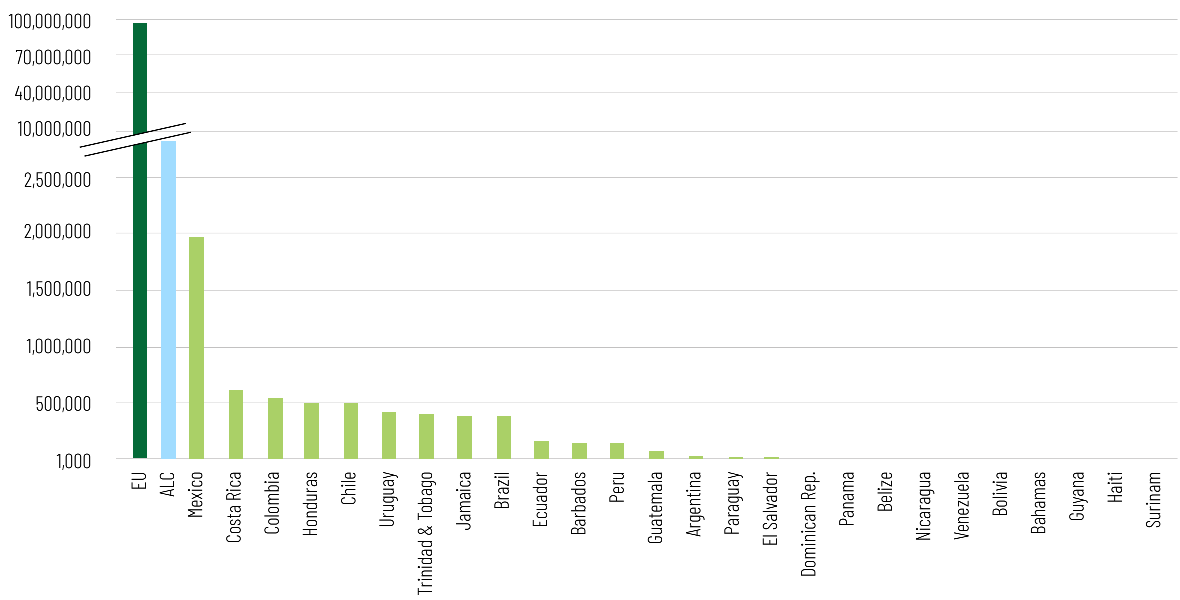
Other countries with a much more limited degree of penetration are mostly countries that **have already started a process to establish a regulatory framework that introduces incentives for SM,** either by carrying out a CBA to measure the feasibility of deploying SM and its associated infrastructure, as well as establishing a national strategy to build smart grids or setting specific objectives for full residential implementation.

No publicly available and accessible information on the deployment of SM has been found for the other LAC countries comprised in this report.

If the deployment of SM is gauged by the total number of residential smart meters installed, as can be seen in graph 4, the result varies considerably in terms of the gap compared to Europe, and in the deployment observed in each LAC country.

Graph 4: Number of smart meters installed in homes in LAC and Europe

Source: Prepared by the authors[3]



[3] Data shown using a partially logarithmic scale.

Mexico, despite very limited penetration, ranks first in the region by number of smart meters installed (1,984,186 units), a significant figure meters when compared to the total installed devices in the LAC region (6,195,159 units). Costa Rica (598,188 units), Colombia (538,000 units), Honduras and Chile (500,000 units), Uruguay (418,000 units), Trinidad and Tobago (400,000 units), Jamaica (380,000 units) and Brazil (375,000 units) follow as per units of smart meters deployed.

In these countries, the Government has generally promoted the deployment of SM by **defining responsibilities, technical functionalities and a remuneration model** on SM that creates security and assures profitability to sector utilities charged with installing and operating meters.

Honduras and Trinidad and Tobago have encouraged deployment by the s**ole distributor charged with installing SM devices.** In **Colombia, deployment is supported** by **private investments** from numerous power distribution utilities.

However, **many LAC region** countries have deployed few or no devices and are far from **a massive deployment of SM in their territories.**

A review of LAC countries that have most advanced in deploying SM and European countries has identified some of the main reasons driving greater deployment of SM: (i) **definition of national objectives** to deploy SM; (ii) **mandatory CBA,** in Europe; (iii) **defined required functionalities** of smart meters, as well as the technical regulations, and (iv) **defined regulatory policy recommendations** for viable SM deployment from the economic and social point of view, among others.

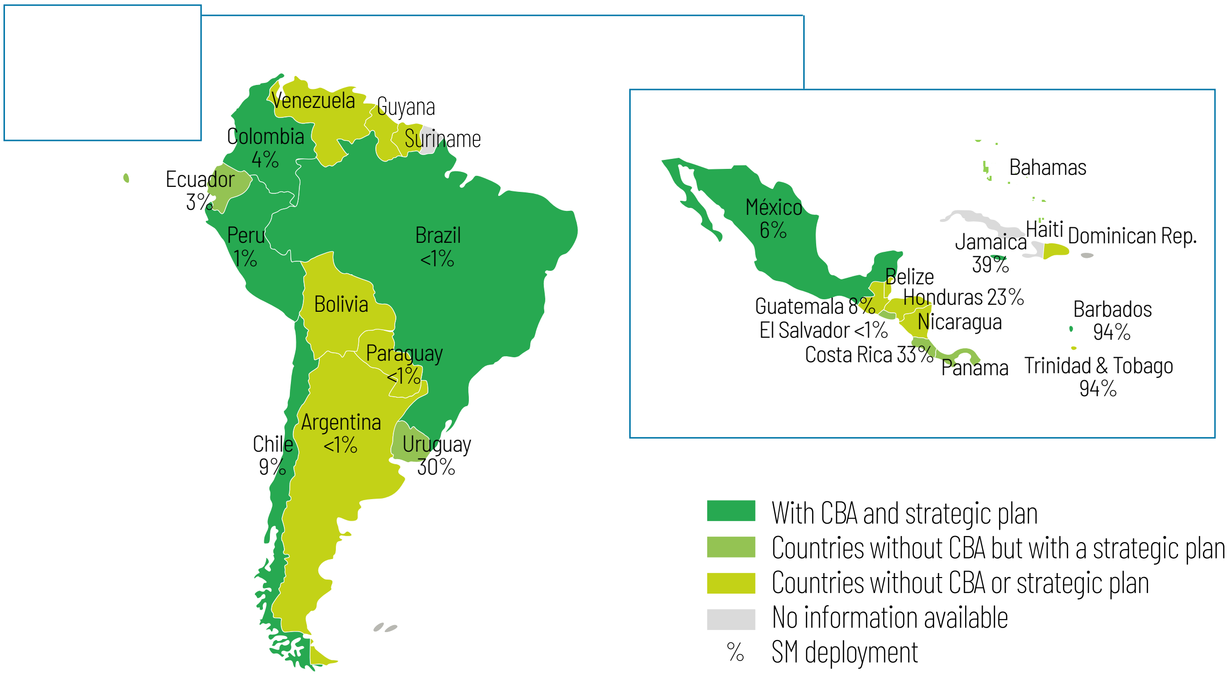
It is worthwhile underscoring that in Europe some specific objectives for SM were defined, and for this reason, the obligation to previously carry out a CBA was established to measure the feasibility of deploying MI. In case of obtaining a positive result from this analysis, the countries should launch the deployment of the SM and the associated infrastructure, including smart meters. Otherwise, **the countries must repeat the CBA exercise every four years to reassess whether favorable conditions already exist for deployment and ensure economic viability.**

In this sense, to promote deployment of SM in LAC countries, **regulators and government agents of each country could create an adequate regulatory SM framework.** To this end, a **CBA to assess the viability of a potential deployment of the SM** and sets forth specific national objectives that encourage the agents involved in the measurement sector to develop SM projects and the design of an adequate regulatory environment are key.

The following illustration shows how various LAC countries have already begun the process of defining a regulatory framework for SM. However, each country has started from different initial conditions (due to their political, economic or social situation), so there has not been a single strategy to design an SM regulatory framework. As a result, the degree of SM deployment varies, and no single and successful methodology can be delimited to achieve SM objectives in the LAC region.

Illustration 3: Analysis of the degree of SM deployment in LAC

Source: Prepared by the authors[4]



In particular, 16 of the 26 countries observed (approximately 62%) have started the process to establish a regulatory environment, by carrying out a CBA and/or by defining a national strategy with specific objectives, or by implementing both mechanisms.

Additionally, it is relevant to mention the case of Panama, a country that has set forth a national strategy and defined the specific objective of reaching 100% of SM deployment by 2024. Nonetheless, it has not been possible to determine based on official or public sources the degree of deployment as of the date of writing this report. This could be mainly because the respon sibility for deploying SM in Panama falls on the electrical distribution utilities which hinders public access to updated data, eventually sending poor signals as to progress in the matter[5].

[4] Wherever the percent of deployment has not been defined, the reason may be it was not possible to identify public and accessible information on SM deployment.
[5] There could be electricity distributors that have begun to deploy SM but have not made public their degree of progress.

In this sense, **public access to and availability of data on the degree of deployment of SM is one of the limiting factors** that can influence the global image of the region and of each country regarding the degree of development in SM.

Throughout this report, based on publicly available information, the main determining causes that have encouraged the deployment of SM in certain countries of the LAC region will be studied, as well as the main challenges that have been faced by the electricity sector and that have been a barrier to the deployment of the SM.

Optimal process to create a regulatory framework to encourage SM in LAC

The current evolution of SM in LAC is characterized in general terms by a lack of harmonization between the regulations developed and the technical characterization of the solutions implemented across countries, with lack of specific regulations in some countries. This leads to a very disparate set of national solutions in the region. The different rhythm in deploying SM in the countries of the LAC region and the lack of homogeneity in the strategies developed in the countries that are making progress in this deployment in turn create **additional costs that may be incurred in other regions with better aligned strategies, limiting the possible economies of scale that could benefit all stakeholders and generating new obstacles for a possible integration of different existing electricity markets in LAC.**

It is essential to understand that harmonization does not mean, however, that a single solution must be imposed to establish a regulatory framework for SM or to define which SM technologies will be considered. Given the existing differences in current circumstances and needs of countries' different electrical systems, their political and economic environment, available SM technologies and the context of each country and its society in general result in different objectives and needs of regulators, electricity network operators, electricity consumers and other interested players. Harmonization should be considered as a recommendation, taking into account the specific circumstances of each country, but which allows, in general terms, to carry out balanced strategies between interested countries.

The main objective of this section is to analyze in greater depth the situation of SM in LAC and the strategies implemented in each country to carry out its implementation, if applicable. To this end, to prepare this report, available public information was reviewed for each of the 26 countries. In particular, an attempt has been made to identify those aspects considered fundamental for SM deployment: preparing a CBA, definition of a national strategy and some specific objectives on the deployment of SM, and the existence of a relevant regulatory framework.

Cost-Benefit Analysis driving the definition of the SM regulatory framework

In the last decade, the debate on the deployment of SM as a fundamental unit to build smart grids has focused mainly on the identification of use cases derived from the development of this technology, as well as how to quantify the benefits derived from such uses. Advanced SM technologies require significant capital investments to replace or improve existing equipment and associated electrical infrastructure. Such investments can contribute to optimizing energy consumption, the costs associated with the electrical system, the reduction of CO2 emissions and to creating new jobs, among other benefits. Therefore, an **economic analysis is required to determine** if a project of such magnitude whose objective is the deployment of SM at the **national or regional level, provides enough benefits to justify the costs to be incurred.**

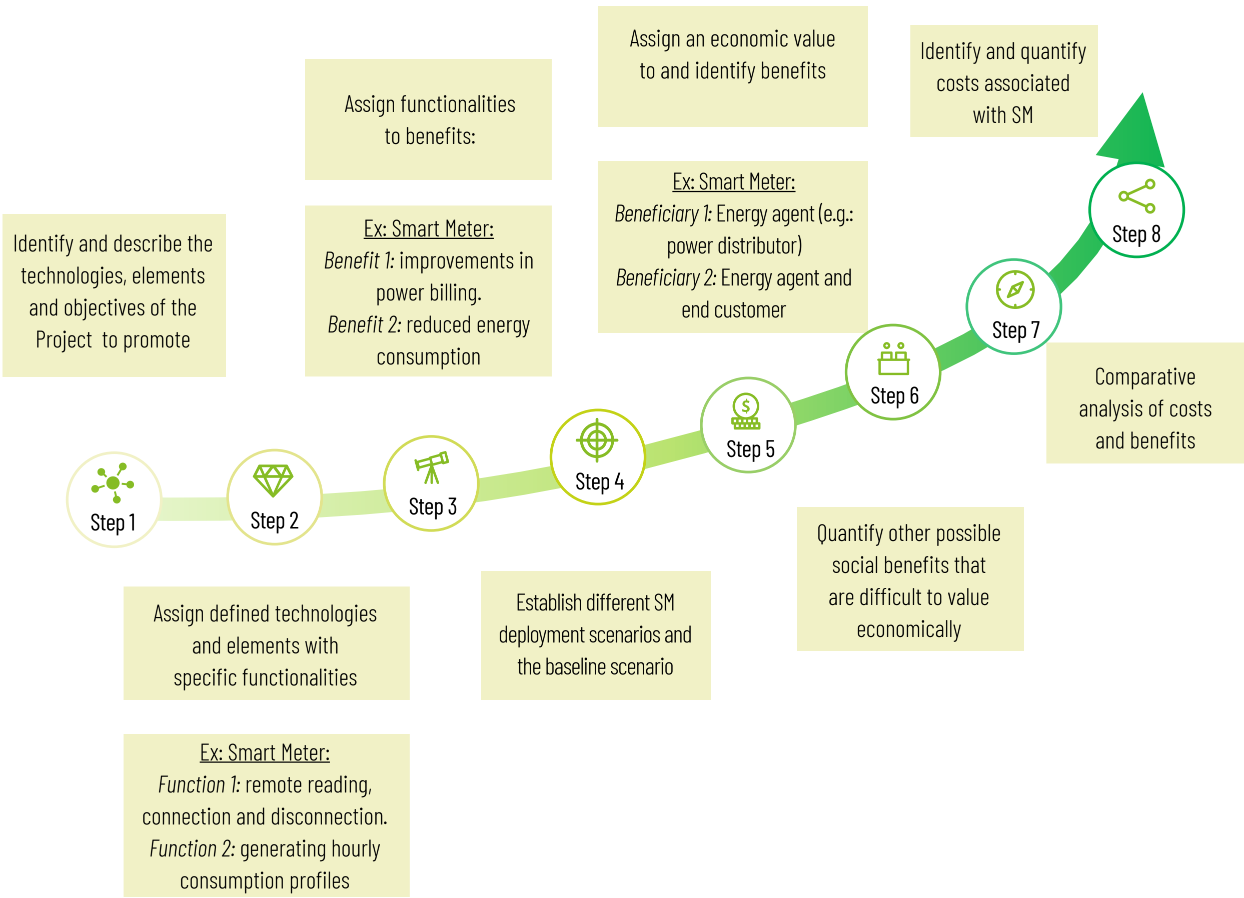
Many countries and regions worldwide, prior to the deployment of smart metering, have carried out a **CBA, understanding it as a step prior to the definition of the relevant regulatory framework, with the aim of measuring the socioeconomic and environmental impact of introducing smart meters and, consequently, the promotion of smart electricity grids.**

In general terms, the methodology applied to carry out a CBA is very consistent and homogeneous at an international level. In this report, some specific mentions are made of the methodology developed by the European Commission in the field of SM. This methodology, widely applied globally, provides a clear guide for the analysis of the costs and benefits of a national SM project.

The following illustration details the main stages that are generally structured around a CBA to deploy SM.

Illustration 4: Main stages of a CBA

Source: Prepared by the authors[6]



Although CBAs are a widespread international best practice tool to analyze the suitability of an SM deployment (and advanced metering infrastructure[7]), such practice in the LAC region has not been as widespread, as shown in the following table, where only in 6 countries of the total studied in the LAC region (approximately 23%) were singled out as having carried our such CBA. As for the rest of the countries, the analysis may not have been carried out, or its results have not been made public.

The following table shows, for the LAC countries under review where the CBA has been performed, and specifically, where a CBA has been made public, the year of their publication, outcomes and the degree of deployment of available SM.

[6] Own elaboration based on the European methodology published in 2012 for carrying out a CBA for the deployment of smart metering. Source: European Commission 2012: Guidelines for cost benefit analysis of smart metering deployment - Publications Office of the EU (europa.eu)

[7] AMI for its acronym in English.

Table 1: Analysis on the performance of CBA in LAC countries for SM deployment (Organized by Deployment %)

Source: Prepared by the authors

<table>
<tr><th>Country</th><th>CBA[8]</th><th>CBA result</th><th>Deployment %</th></tr>
<tr><td>Trinidad and Tobago</td><td rowspan="2">Not available</td><td>Not available</td><td>94%</td></tr>
<tr><td>Barbados</td><td>Not available</td><td>94%</td></tr>
<tr><td>Jamaica</td><td>2019</td><td>Positive</td><td>39%</td></tr>
<tr><td>Costa Rica</td><td rowspan="3">Not available</td><td>Not available</td><td>33%</td></tr>
<tr><td>Uruguay</td><td>Not available</td><td>30%</td></tr>
<tr><td>Honduras</td><td>Not available</td><td>23%</td></tr>
<tr><td>Chile</td><td>2013</td><td>Inconclusive</td><td>9%</td></tr>
<tr><td>Guatemala</td><td>Not available</td><td>Not available</td><td>8%</td></tr>
<tr><td>Mexico</td><td>2014</td><td>Positive</td><td>6%</td></tr>
<tr><td>Colombia</td><td>2020</td><td>Positive</td><td>4%</td></tr>
<tr><td>Ecuador</td><td>Not available</td><td>Not available</td><td>3%</td></tr>
<tr><td>Peru</td><td>2019</td><td>Inconclusive</td><td>1%</td></tr>
<tr><td>Paraguay</td><td>Not available</td><td>Not available</td><td>< 1%</td></tr>
<tr><td>Brazil</td><td>2010</td><td>Positive</td><td>< 1%</td></tr>
<tr><td>El Salvador</td><td rowspan="12">Not available</td><td rowspan="12">Not available</td><td>< 1%</td></tr>
<tr><td>Argentina</td><td>< 1%</td></tr>
<tr><td>Dominican Republic</td><td rowspan="10">Not available</td></tr>
<tr><td>Panama</td></tr>
<tr><td>Belize</td></tr>
<tr><td>Nicaragua</td></tr>
<tr><td>Venezuela</td></tr>
<tr><td>Bolivia</td></tr>
<tr><td>Bahamas</td></tr>
<tr><td>Guyana</td></tr>
<tr><td>Haiti</td></tr>
<tr><td>Suriname</td></tr>
</table>

[8] For countries in which a CBA for SM has been identified, the latest analysis carried out and publicly available for the country is considered and the date on which the document was published is specified.

Some countries, and specifically **Mexico, Chile and Brazil, moved first in identifying the need to deploy SM** and carried out their CBAs in 2014, 2013 and 2010, respectively. However, during those years, SM was not as relevant as at present and in these countries, the analysis carried out did not have a great impact as evidenced by low current degree of SM deployment in these countries.

Given the rapid technological evolution, it is recommended that regulators and government agents plan regular **CBA updates so analyses will reflect effective recent developments in the electricity market and SM.**

It is important to highlight that the **result of the CBA depends directly on the costs and benefits that are considered during the analysis.**

Next, the CBA carried out for SM is examined in more detail and, more specifically, the cost items considered by the 6 LAC countries having performed a CBA.

Illustration 5: Costs considered in the CBA carried out by LAC countries.
Source: Prepared by the authors

	Brazil	Chile	Colombia	Jamaica	Mexico	Peru
CAPEX associated with MI	✓	✓	✓	✓	✓	✓
CAPEX associated with AMI	✓	✓	✓	✓	✓	✓
OPEX associated with MI	✓	✓	✗	✗	✗	✓
OPEX associated with AMI	✓	✓	✗	✗	✗	✓

The **initial investments to deploy SM, particularly the smart meters and the associated advanced metering infrastructure,** were considered by 100% of the countries for which a CBA has been identified. However, other cost items typically considered in a CBA are the **operation and maintenance costs** related to both SM and its infrastructure; however, **only 3 of the 6 countries, and specifically, Chile, Brazil and Peru, have considered** them when carrying out their CBAs.

In a CBA, the costs associated with the operation and maintenance of smart meters supposes an increase in the total costs associated with SM deployment and, therefore, there is a direct impact on the final CBA. Chile and Peru's CBAs were inconclusive. Therefore, the prior identification and definition of the costs associated with SM is highly relevant to the result of the analysis, as well as the decisions and developments that may arise as a consequence of such CBA. However, **not considering certain costs in the CBA study can lead to unplanned costs emerging during the deployment and hamper SM deployment.**

Additionally, **the identification and evaluation of the possible benefits derived from SM is also of considerable relevance.** The following illustration provides an overview of the range of potential benefits considered by LAC countries when performing a CBA on SM:

Illustration 6: Benefits considered in CBAs in LAC countries

Source: Prepared by the authors

	Brazil	Chile	Colombia	Jamaica	Mexico	Peru
Improved management of interruptions and supply cuts	✓	✓	✓	✓	✓	✓
Reduction of technical losses	✓	✓	✓	✓	✓	✓
Cost reduction associated with the operation and maintenance of meters	✓	✓	✓	✓	✓	✓
Savings associated with reading of meters	✓	✓	✓	✓	✓	✓
Reduction of non-technical losses (including losses associated with fraud)	✓	✗	✓	✓	✓	✓
Enabling of hourly rates that allow efficiency of energy consumption	✓	✓	✓	✓	✓	✗
Reduction of the carbon footprint associated with better use of energy generated	✓	✗	✓	✗	✓	✓
Enabling a development of a market retailer with greater competition and the integration of new lending agents	✓	✗	✓	✗	✗	✗
Enabling flexibility services	✗	✗	✓	✗	✗	✓
Efficiencies in investment planning networking	✗	✗	✓	✗	✗	✓
Enabling the development of self-consumption, energy communities, by making it possible to collect bidirectional periodic consumption	✗	✓	✗	✗	✗	✗

The **most common benefits** that LAC countries have considered in carrying out their CBA to deploy SM include (i) improved management of electricity service interruptions and power outages, (ii) reduced technical losses, (iii) lower cost to operate and maintain smart meters, and (iv) lower cost of meter reading. Additionally, 5 out of 6 countries (approximately 83%) that have carried out a CBA on SM have considered as a possible **benefit** the reduction of

non-technical losses, related to fraud and informal mechanisms. This is a very relevant factor for some LAC countries, since the implementation of SM could allow to adopt schemes for their rapid detection and consequently their reduction. Likewise, another benefit considered by 5 out of these 6 countries has been the possibility of adopting **hourly electricity rates** that allow sending adequate market signals to consumers about peak usage periods, thus encouraging more efficient energy consumption management by end consumers, and therefore generating savings both in costs for the electricity system itself and for end consumers in their electricity bill.

However, the benefits associated with the development of numerous services that could be offered to consumers, derived from the development of SM, and that would allow the proliferation of flexibility services and more competitive markets, with the integration of new energy agents or the development of new ecosystems, such as self-consumption, have only been considered by a few LAC countries.

Including in this analysis the benefits associated with new trends in the electricity sector that are already apparent in many countries, **is essential in any CBA that examines the industry's existing environment.**

Enabling the development of a more competitive retail market that involves new players providing energy services, as well as demand driven response mechanisms are benefits derived from the deployment of SM that if not taken into account when carrying out a CBA, **can lead to an inconclusive or negative result and send an inadequate signal to the market about the impact of deploying SM on the country's electricity grid.**

The outcomes of different CBAs carried out in LAC countries show **that omitting certain costs and benefits can have a relevant impact on the result of the analysis** and with it, the final decision to foster SM.

Prepare a National Strategy that promotes the definition of a specific SM regulatory framework

Preparing a national strategy is a habitual practice to lay down the foundations of schemes to address SM needs and to design the intended regulatory framework. This approach complements and leverages the results of the CBA.

Due to the direct relationship between **SM, smart electrical grids and the digitization of networks,** it is usual to develop a strategy that integrates the three variables and contemplates the specific definition of objectives to achieve massive SM deployment.

The overall objective of a strategy, whether national or regional, is to systematically align activities and capabilities to achieve clearly defined objectives, in this case, fostering SM deployment. The strategies are, therefore, useful tools developed by countries to create a mechanism that brings together all relevant players who can thus contribute to achieving shared goals and objectives.

Developing a national strategy in LAC countries that encourages SM sends, among other things, a **strong policy signal,** both nationally and internationally, warranting **the mobilization of efforts and resources, and enhancing security for companies playing in the field of SM, especially regarding the investments in this technology.**

Bringing SM to different sectors, even entire countries, through the definition of national and regional strategies to implement SM, can effectively contribute to creating synergies between public and private entities and organizations, to try to address the national and regional challenges involved in deploying SM.

To this end, it is desirable that the strategies' clear rationale should start by **listing the general goals and conclude by defining specific objectives for the deployment of SM,** clarifying the necessary transition towards a smart electricity grid through objectives and support measures, activities, capabilities, and tactics. It is important to highlight that even though the general objective of the SM strategies is to encourage deployment, the way in which the challenge is addressed in each country or region and, therefore, the measures and tactics needed will vary depending on the specific context of each country or region.

Additionally, the international experiences derived from the development of strategies in relation to SM, electrical networks and their digitization have highlighted the need to **periodically reassess the strategies** once defined. **Smart grid technologies evolve much faster than traditional service assets developed in the industry so far.** So, a best practice for smart grid deployment is the continuous evaluation of these enabling technologies. That is why those countries that define a SM strategy typically consider it as **a living document that is constantly updated** to reflect the changes and learnings that take place over time, just as it could occur with certain elements of the eventual SM **regulatory framework.**

The following table shows the list of LAC countries that have defined national SM strategies, either specifically or included in a broader strategy for electricity grids or their digitization, as well as their year of publication and degree of deployment in each country.

Table 2: LAC countries with a defined National Strategy highlighting SM (Organized by Deployment %)
Source: Prepared by the authors

Country	Deployment	Strategy name	Year of publication
Barbados	94%	National Energy Policy 2019-2030	2019
Jamaica	39%	JPSCo 5 Year Business Plan (2019-2024)	2019
Costa Rica	33%	National Smart Power Grid Strategy	2021
Uruguay	30%	UTE Strategic Plan 2020-2021	2020
Chile	9%	Smart Grids: Development opportunities and implementation strategy	2013
Mexico	6%	Smart Grid Program	2017
Colombia	4%	Smart Grids: Colombia Vision 2030	2016
Ecuador	3%	National Energy Efficiency Plan 2016-2035	2016
Peru	1%	Draft Smart Grid Regulations	2018
Brazil	< 1%	National Energy Plan - PNE2050	2020
El Salvador	< 1%	Energy Policy 2020-2050	2020
Panama	Not available	National Distributed Generation Plan	2021
Bahamas	Not available	The Bahamas National Energy Policy (2013-2033)	2013

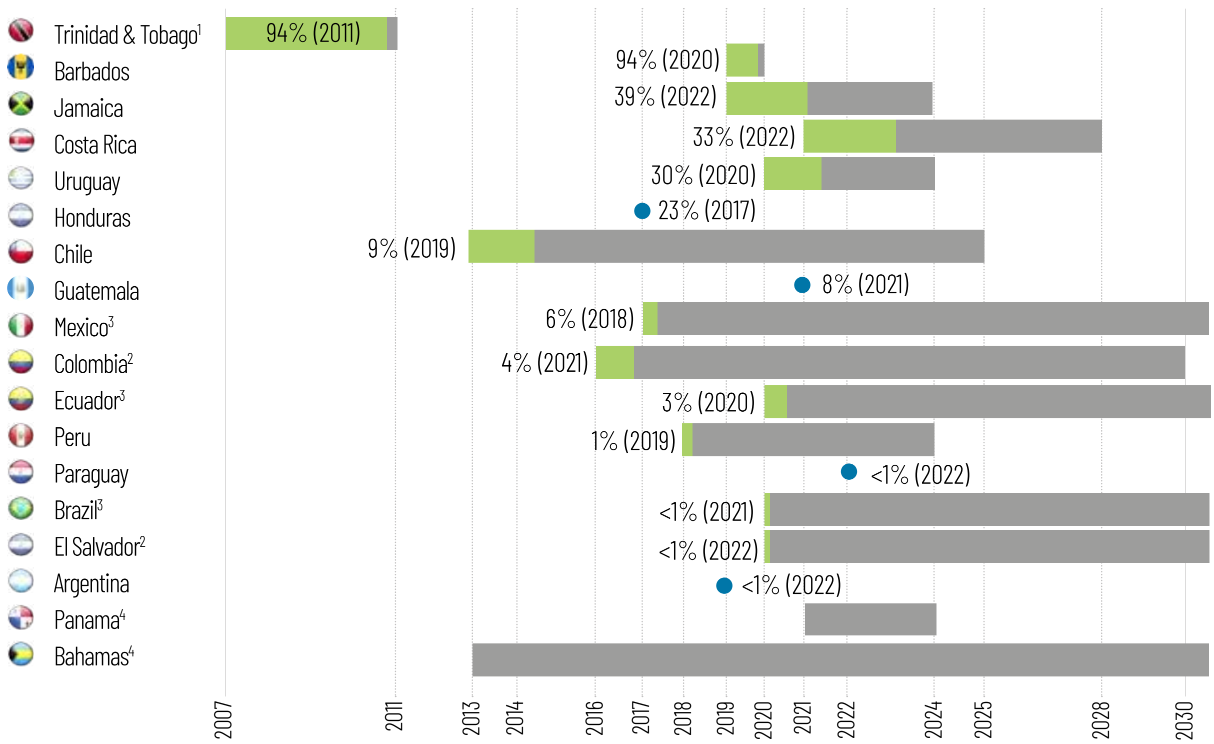
A total 13 of the LAC countries reviewed (50% of the total countries studied) have defined strategies and specific objectives to encourage SM. Most of these strategies were prepared starting in 2018 and they have not been updated. In particular, Chile, with a degree of deployment of 9%, and the Bahamas, with a degree of deployment not officially or publicly available, developed their respective strategies in 2013, when they already considered the relevance of SM with a view to a future electricity sector where smart electricity grids play a fundamental role. In this sense, updating these strategies would be advisable to thus consider progress in digital technologies and their multiple applications in electricity networks and meters.

Likewise, only some of the countries that have defined a national strategy have carried out a CBA for SM deployment. Table 1 shows positive results in Jamaica, Mexico, Colombia and Brazil while results were inconclusive in Chile and Peru.

Additionally, the following illustration presents for each LAC country the degree of SM deployment compared to national strategy stated objectives if actually defined their respective strategy.

Illustration 7: LAC countries with a certain degree of SM deployment in and national strategies' objectives

Source: Prepared by the authors



() The year of the data is shown in brackets.
All strategic plans are current

1 Trinidad and Tobago does not have a national strategic plan but does have a project from its power utility

2 Colombia's objective for 2030 is to reach 75% SM deployment.

3 These countries present a general strategic energy plan and not SM in particular. Therefore there is no end date.

4 The data on deployment degree is not publicly available and accessible.

● Information is available only regarding deployment degree

The length of the bars indicates the SM implementation development period from the beginning of the strategic plan to the target date.

In general, the defined strategies aim at 100% deployment between the years 2024 and 2030. Colombia has defined a deployment objective of 75% for 2030. Bearing in mind that, in 2021, its degree of deployment was 4%, it will be necessary to adopt additional measures, both regulatory and technical, to foster SM implementations.

Honduras (23%), Guatemala (8%), Paraguay (<1%) and Argentina (<1%) have begun deploying SM but have not defined specific national objectives or a strategy to encourage implementation. Trinidad and Tobago, with a project defined by its electricity company in 2007, had reached 94% penetration as of 2011. It should be noted that the functionalities that were defined in 2007 to consider meters as intelligent only required remote reading capabilities, without considering all the functionalities that are currently required to achieve SM status. The project was prepared at a time prior to the emergence of present SM technologies. Therefore, Trinidad and Tobago could update its definition of SM and adapt it to new digital electrical grid requirements.

Another characteristic worth considering is whether the national strategy to foster SM is included in a strategy for smart electricity grids, for grid digitization, or for the transition of the energy sector towards a decarbonized and renewables model. The definition of a global strategy for the energy sector could contemplate a greater number of relevant ecosystems for the future, such as renewable generation, decarbonization of the transport sector or SM, and others. However, there is a risk that a global strategy does not sufficiently detail the specific needs of each ecosystem and, specifically, SM, not defining clear objectives to deploy SM. This fact could explain that countries like Mexico (with a SM degree of deployment of approximately 6%), Ecuador (approximately 3%), Brazil (below 1%) or El Salvador (less than 1%), that have defined a global strategy for the energy sector have not however achieved large scale residential SM implementation.

Structure regulatory mechanisms that encourage the deployment of SM in LAC

Range of regulatory approaches to foster SM deployment

The choice of legislative and regulatory tools to promote SM depends not only on the (national) legal framework and the phase of market liberalization, but also on the motivation of end consumers to adopt residential SM. This last fact will depend directly on the possible benefits and economic costs derived from the implementation of SM finally transferred to the final consumer.

The type of metering regime applied (regulated or liberalized) can influence the real benefits obtained from SM and its profitability as an investment for the agents involved in the sector. In this sense, many of the countries that have begun deploying SM, regulate it. Only some companies are authorized to carry it out and their remuneration is subject to regulation. In countries with a regulated metering market, the allowed revenues, system costs and the corresponding metering rates are defined both for the agent that bears the costs and for the users who use SM. Examples of such countries include Colombia, Peru, Chile, Brazil, Mexico, among others.

However, in some countries, measurement is a competitive, free market activity. In these cases, any agent can offer the metering service and there would be no regulated metering rates or a regulatory mechanism for the recovery of the costs associated with SM. In many existing market models, an unregulated free market would not make it possible to guarantee the recovery of the investments made and obtaining profitable returns in all situations, hampering deployment, with a high risk for the agents who want to participate in this process.

Regardless of the metering regime adopted, whether regulated or free market, government entities or regulators (in the regulated metering regime) can encourage or urge electricity companies to implement SM in their electricity networks by creating an adequate regulatory framework that establishes, among other initiatives, a deadline for the replacement of all existing electromechanical meters by smart meters.

Government bodies and regulatory authorities may take different approaches for SM deployment. Below appear some alternatives, with different degrees of requirements:

1. **Remove legal or regulatory obstacles to SM**, allowing its deployment but without coercing sector players.

2. **Set forth specific service criteria**, for example, monthly electricity billing is based on measured hourly data, **without making any particular reference to SM functionalities**, but encouraging its deployment. This makes it possible to reinforce the need for SM to provide detailed invoicing without determining which technologies can meet the defined specific criteria.

3. Force the deployment of SM by **defining the minimum functionalities** to be met by residential meters. Also, some **incentives or financial compensation** can be established to guarantee the profitability of implementing utilities.

4. **Mandate the deployment of SM without establishing incentives or financial compensation**.

Establishing the mandatory deployment without establishing incentives or financial compensation is not a desirable instrument due to the possibility of fostering widespread social discontent.

A combination of some of the four options defined above to achieve the deployment of SM is also a valid option that could encourage the process considering specific country circumstances.

The following table lists the regulatory approaches adopted by the LAC countries under review, ranked by degree of SM deployment:

Table 3: Regulatory approach to encourage SM deployment by LAC country (Organized by Deployment %)

Source: Prepared by the authors

<table>
<tr><th>Country</th><th>Deployment</th><th>Who is in charge</th><th>Deployment (%)</th></tr>
<tr><td>Trinidad and Tobago</td><td>DSO</td><td rowspan="3">Not available</td><td>94%</td></tr>
<tr><td>Barbados</td><td>Not available</td><td>94%</td></tr>
<tr><td>Jamaica</td><td rowspan="10">DSO</td><td>39%</td></tr>
<tr><td>Costa Rica</td><td>Mandatory</td><td>33%</td></tr>
<tr><td>Uruguay</td><td>Voluntary</td><td>30%</td></tr>
<tr><td>Honduras</td><td>Not available</td><td>23%</td></tr>
<tr><td>Chile</td><td rowspan="2">Voluntary</td><td>9%</td></tr>
<tr><td>Guatemala</td><td>8%</td></tr>
<tr><td>Mexico</td><td>Not available</td><td>6%</td></tr>
<tr><td>Colombia</td><td>Voluntary</td><td>4%</td></tr>
<tr><td>Ecuador</td><td>Not available</td><td>3%</td></tr>
<tr><td>Peru</td><td>Mandatory</td><td>1%</td></tr>
<tr><td>Paraguay</td><td>Not available</td><td>Not available</td><td>< 1%</td></tr>
<tr><td>Brazil</td><td>DSO</td><td>Mandatory</td><td>< 1%</td></tr>
<tr><td>El Salvador</td><td>Not available</td><td>Voluntary</td><td>< 1%</td></tr>
<tr><td>Argentina</td><td rowspan="2">DSO</td><td>Mandatory</td><td>< 1%</td></tr>
<tr><td>Panama</td><td>Not available</td><td>Not available</td></tr>
</table>

<table>
<tr><th>Country</th><th>Deployment</th><th>Who is in charge</th><th>Deployment (%)</th></tr>
<tr><td>Dominican Republic</td><td>DSO</td><td rowspan="9">Not available</td><td rowspan="9">Not available</td></tr>
<tr><td>Suriname</td><td rowspan="8">Not available
Not available</td></tr>
<tr><td>Venezuela</td></tr>
<tr><td>Bahamas</td></tr>
<tr><td>Belize</td></tr>
<tr><td>Bolivia</td></tr>
<tr><td>Guyana</td></tr>
<tr><td>Haiti</td></tr>
<tr><td>Nicaragua</td></tr>
</table>

Approximately 19% of the LAC countries studied (Uruguay, Chile, Guatemala, Colombia and El Salvador) expressly require voluntary residential SM. In El Salvador, however, electricity distributors are made responsible for SM deployment. Additionally, approximately 15% of the LAC countries studied have defined the obligation to implement smart meters in all homes, with the country's electricity distributors also being responsible for the deployment.

One of the **advantages of establishing the voluntary nature of the installation** of smart meters in homes is to give greater control and decision-making power to users, thus reducing the likelihood of social rejection to meter installation. The voluntary deployment of the meters is usually implemented when there is not clear knowledge of the potential economic and technical benefits of installing residential SM, both for users and for the country's power grid.

Nonetheless, voluntary deployment may hamper the achievement of **specific objectives as lack of robust incentives may make players to move slowly, and eventually increase costs for both marketing and installation,** by preventing to reach economies of scale if only a small number of smart meters is installed.

Additionally, as can be seen from the table above, **those countries that have started deployment have defined, among others, the type of deployment and the agent responsible for implementation.** Consequently, **regulating the smart metering environment gives greater security to the agents involved, encourages economic investments, and thus make it possible to launch deployment.**

With respect to the LAC countries studied for this report, only one country (Barbados) has been identified that, having defined a deployment objective for SM[9], has not established a deployment approach (mandatory or voluntary) nor identified the responsible player. However, Barbados has a single power distribution utility fully charged with running the country's electrical distribution system, and thus charged with meter installation.

Main areas identified for regulation to guarantee successful SM deployment

A) Technical functionalities

As far as technical issues are concerned, the most common approach is to define standards or minimum requirements regarding the **design of smart meters**, such as what variables should be measured, what information should be displayed locally, etc., as well as, **regarding the operation of the meter itself**, such how data can be transmitted, communication protocols, frequency of meter readings, etc.

Defining minimum meter functionalities is a critical first step in developing the regulatory environment for SM. On the one hand, the number and type of functionalities determine its potential benefits and, on the other, influences the cost of the SM system. That is why, in countries with regulated electricity markets, where the regulator defines the costs associated with the installation and operation and maintenance of the SM, **the defined financing mechanism should adequately contemplate the total cost of the same to ensure cost recovery.**

Even in competitive SM markets, setting minimum functional requirements or technical standards will facilitate interoperability, allowing end-users to switch providers without facing potential technical barriers. When the metering market is open to competition, the suppliers and the customers decide on the type of meter. Therefore, it will be necessary to define certain levels of standardization and interoperability between devices and systems.

[9] See Table 15 for SM deployment strategies included in Annex III.

Countries that have defined certain minimum functionalities in the SM environment are listed below:

Table 4: LAC countries that have defined minimum SM technical functionalities (Organized by Deployment %)

Source: Prepared by the authors

Country	Year	Deployment
Trinidad and Tobago	Not available	94%
Barbados		94%
Jamaica	2021	39%
Costa Rica	2022	33%
Uruguay	2021	30%
Honduras	Not available	23%
Chile	2019	9%
Guatemala	Not available	8%
Mexico	2015	6%
Colombia	2018	4%
Ecuador	Not available	3%
Peru		2017
Paraguay		2020
Brazil		Not available
El Salvador		< 1%
Argentina		< 1%
Panama		2017
Dominican Republic		Not available
Bahamas		
Belize		
Bolivia		
Guyana		
Haiti		
Nicaragua		
Surinam		
Venezuela		

The above table shows only 10 of the LAC countries (approximately 38%) had defined the minimum functionalities required for smart meters between 2015 and 2022 when this report was prepared. Given ongoing updating and improvement of the technologies involved in developing SM, we recommend Mexico, Panama and Peru that defined these functionalities in 2015 and 2017, reassess them to take into consideration presently available technologies. Brazil has defined the functionalities of smart meters as recently as 2022, but the documentation was not available publicly at the time of the preparation of this report.

The following illustration identifies the main functionalities defined by those countries, with information in the public domain, that have defined the minimum SM requirements.

Illustration 8: Technical functionalities considered by LAC countries

Source: Prepared by the authors

	Argentina	Chile	Colombia	Costa Rica	Jamaica	Mexico	Panama	Peru	Uruguay
Provides reactive power readings	✓	✓	✓	✓	✓	✓	✗	✓	✓
Reading frequency	✗	✓	✓	✗	✓	✓	✓	✓	✓
Stored history	✓	✓	✓	✗	✓	✓	✓	✗	✓
Allows remote readings to the operator	✗	✓	✓	✗	✓	✓	✓	✓	✓
Allows remote on/off control of the supply	✓	✓	✓	✓	✗	✓	✗	✓	✓
Allows two-way communication for maintenance and control	✓	✓	✓	✗	✗	✓	✗	✓	✓
There are security protocols in communication	✗	✓	✓	✓	✗	✓	✗	✗	✓
There are fraud detection and prevention protocols	✗	✓	✓	✓	✗	✓	✗	✗	✓
Allows consumption/power limitation	✗	✓	✓	✓	✗	✗	✗	✓	✗
Allows modifications of access conditions	✗	✓	✗	✗	✗	✗	✗	✗	✓

The previous illustration shows how 8 of the 9 countries for which public information was available require reactive energy readings. The main objective of incorporating this functionality is to support a definition of rates that include charges (or penalties) for reactive energy to reflect the impact on the network of a deficient power factor and/or promote its correction. The functionalities that have been defined by 7 of the countries studied include: (i) defined frequency of SM readings to incorporate hourly rates and encourage demand response; (ii) reading logs to prepare customer load curves and design electricity rates adjusted to consumer profiles; (iii) remote reading to encourage costs reductions associated with reading and foster digitization of power billing systems and, (iv) remote on/off supply control to permit balancing power supply and demand, to guarantee stable system voltage within the permitted ranges and/or maximize load (and load loss) factors and thereby minimize losses and optimize network utilization.

In addition to the technical functionalities considered in the previous illustration, a common international regulatory practice is to define **minimum meter characteristics, stability of supply and operation, and other commercial aspects required by the operating distributor and end clients.**

The following table shows the main technical functionalities that have been identified during the study of the regulatory frameworks defined in other countries worldwide:

Table 5: Main technical functionalities defined in national regulatory frameworks

Source: Prepared by the authors

Functionalities	
Meter features	Internal data storage
	Ability to integrate measurements from different services
	Meter time synchronization
	Remote meter setup
	Adjustment of parameters such as reading intervals, rates and duration of periods, etc.
	Remote meter update (Software, firmware, etc.)
Safety	Prevent and detect fraud in the supply and manipulation of equipment
	Support secure data communications

Functionalities	
Measurement operator	Allow remote meter reading
	Two-way communication between the meter and other elements
	Provide power quality measurements
Commercial power supply considerations	Accept advanced charging systems
	Provision of the service through prepaid systems
	Remote connection/disconnection of supply and/or flow or power restrictions
Distributed generation	Two-way energy measurement (energy import/export)
Clients	User access to meter information
	Integrate solutions to enable demand driven response

Given the technical and economic peculiarities of the LAC countries reviewed here, the definition or updating of the regulatory framework that sets forth minimum SM functionalities must consider the general needs and benefits that are sought to be achieved through SM, the flow of data and the parties involved, as well as the potential impact of implementing these functionalities.

B) Ownership of smart meters

In most countries, meters installed to perform consumption readings belong to the electricity distributor. However, other options are possible depending on the country. For example, the meter can be owned by the electricity distributor, the retailer, the measuring company or the final consumer. Determining the owner of the meter is a decision that can significantly influence the investment in SM and thereby the degree of deployment that can be achieved in the country. For example, when the meter belongs to the final consumer, the consumer may be unwilling to change their meter or take responsibility for the cost associated with its implementation and operation. Consequently, when defining the ownership regulatory framework, it will be key to consider the opinion of the agents involved in the SM sector, as well as defining their financing mechanism. The following table shows the ownership of smart meters in the LAC countries reviewed here:

Table 6: Ownership of smart meters in LAC countries
(Organized by Deployment %)

Source: Prepared by the authors

<table>
<tr><th>Country</th><th>Ownership</th><th>Deployment (%)</th></tr>
<tr><td>Trinidad and Tobago</td><td>Electricity distributor</td><td>94,12</td></tr>
<tr><td>Barbados</td><td>Not available</td><td>94</td></tr>
<tr><td>Jamaica</td><td rowspan="10">Electricity distributor</td><td>39,3</td></tr>
<tr><td>Costa Rica</td><td>33,23</td></tr>
<tr><td>Uruguay</td><td>30,08</td></tr>
<tr><td>Honduras</td><td>23,23</td></tr>
<tr><td>Chile</td><td>8,85</td></tr>
<tr><td>Guatemala</td><td>8,42</td></tr>
<tr><td>Mexico</td><td>5,63</td></tr>
<tr><td>Colombia</td><td>3,92</td></tr>
<tr><td>Ecuador</td><td>3,12</td></tr>
<tr><td>Peru</td><td>1,31</td></tr>
<tr><td>Paraguay</td><td>Not available</td><td>0,53</td></tr>
<tr><td>Brazil</td><td>Electricity distributor</td><td>0,52</td></tr>
<tr><td>El Salvador</td><td>Not available</td><td>0,45</td></tr>
<tr><td>Argentina</td><td rowspan="3">Electricity distributor</td><td>0,16</td></tr>
<tr><td>Panama</td><td rowspan="10">Not available</td></tr>
<tr><td>Dominican Republic</td></tr>
<tr><td>Bahamas</td><td rowspan="8">Not available</td></tr>
<tr><td>Belize</td></tr>
<tr><td>Bolivia</td></tr>
<tr><td>Guyana</td></tr>
<tr><td>Haiti</td></tr>
<tr><td>Nicaragua</td></tr>
<tr><td>Surinam</td></tr>
<tr><td>Venezuela</td></tr>
</table>

In general, as shown in table, 15 of all LAC countries reviewed here (approximately 58%) have defined ownership of smart meters. The responsibility, in these cases, has been assigned to the electricity distributor, in a manner consistent with the successful regulatory frameworks developed in other international experiences, where the electricity distributor is generally defined as both the owner and the agent responsible for the deployment of SM. **Establishing criteria that provide homogeneous responsibilities facilitates decision-making and, therefore, SM deployment in the countries' electricity grid.**

C) Financing mechanism for smart meters and associated SM infrastructure.

Defining SM financing regulations is one of the most important elements for a successful SM deployment. Therefore, regulatory design and definition of the structure that supports the economic costs of SM, whether through fees, government subsidies and/or well-designed incentives, will be crucial to guarantee large-scale deployment in the countries and the resulting transition to smart grids.

Below are some of the **main basic principles for the SM financing schemes and their regulatory structure adopted in numerous countries:**

- **Economic efficiency:** Encourage the best possible use of economic resources, at the lowest cost. A CBA must reflect the costs incurred associated with the meters themselves, their operation and maintenance costs, as well as the costs the SM entails for the electrical system, among others.

- **Equity:** No discrimination in the allocation of costs for users who use the electrical system in a similar way. The financing mechanism will be adjusted to the costs and benefits pertaining to each user.

- **Financial balance:** the financial mechanism must assure all costs are covered to avoid sunk costs for the electrical system and that players in SM deployment shall profit from their investments.

- **Simplicity and transparency:** Design a simple regulatory mechanism, so that it can be understood by end users. Social acceptance of SM is a key element to ensure its deployment, so the way in which smart meters and the advanced metering infrastructure associated with them are financed must be communicated to users in an easy to understand and straightforward manner to get their acceptance.

- **Stability:** Preserve the financing structure of SM deployment for a reasonable time, avoiding short-term changes, so the agents involved in the deployment of SM will perceive legal certainty and so plan the investments necessary to implement SM in the electrical system in the medium and long term.

It is important to highlight, and as will also be seen among LAC countries, that the choice and implementation of the SM financing mechanism in each country is peculiar and characteristic to each, so that there is no single solution that fits all countries. However, it has been identified that most of the countries do design financial mechanisms so that the general benefits of SM such as improved quality and reliability of supply, lower operating costs, and the environmental benefits of energy efficiency, among others, are perceived by all users who will benefit directly or indirectly, so the cost of deploying SM must be borne to a certain extent by all consumers.

Generally, the most widely used financial mechanisms to support SM costs include (i) fully or partially financing or subsidies from government or other public administrations; (ii) economic and fiscal incentives, i.e. taxes or fiscal exemptions, (iii) compensation through electricity tariffs or specific rates/tariffs for users, or (iv) directly by final consumers.

The following table shows the financial mechanism identified and defined in each country for SM deployment, as well as the option between mandatory and voluntary deployment and finally, the degree of SM implementation in each LAC country:

Table 7: Financing mechanisms defined in each LAC country
(Organized by Deployment %)
Source: Prepared by the authors

<table>
<tr><th>Country</th><th>Type</th><th>Mechanism[10]</th><th>Deployment (%)</th></tr>
<tr><td>Trinidad and Tobago</td><td rowspan="3">Not available</td><td>Remuneration - VAD</td><td>94,12</td></tr>
<tr><td>Barbados</td><td>Not available</td><td>94,00</td></tr>
<tr><td>Jamaica</td><td>Client</td><td>39,30</td></tr>
<tr><td>Costa Rica</td><td>Mandatory</td><td rowspan="2">Remuneration - VAD</td><td>33,23</td></tr>
<tr><td>Uruguay</td><td>Voluntary</td><td>30,08</td></tr>
<tr><td>Honduras</td><td>Not available</td><td>Client</td><td>23,23</td></tr>
<tr><td>Chile</td><td rowspan="2">Voluntary</td><td rowspan="2">Remuneration - VAD</td><td>8,85</td></tr>
<tr><td>Guatemala</td><td>8,42</td></tr>
<tr><td>Mexico</td><td>Not available</td><td>Not available</td><td>5,63</td></tr>
<tr><td>Colombia</td><td>Voluntary</td><td rowspan="3">Remuneration - VAD</td><td>3,92</td></tr>
<tr><td>Ecuador</td><td>Not available</td><td>3,12</td></tr>
<tr><td>Peru</td><td>Mandatory</td><td>1,31</td></tr>
<tr><td>Paraguay</td><td>Not available</td><td rowspan="4">Not available</td><td>< 1%</td></tr>
<tr><td>Brazil</td><td>Mandatory</td><td>< 1%</td></tr>
<tr><td>El Salvador</td><td>Voluntary</td><td>< 1%</td></tr>
<tr><td>Argentina</td><td>Mandatory</td><td>< 1%</td></tr>
<tr><td>Panama</td><td rowspan="4">Not available</td><td rowspan="2">Remuneration - VAD</td><td rowspan="4">Not available</td></tr>
<tr><td>Dominican Republic</td></tr>
<tr><td>Bahamas</td><td rowspan="2">Not available</td></tr>
<tr><td>Belize</td></tr>
</table>

[10] Client: borne the cost directly by the final consumers; Remuneration – VAD: Considered in the base of regulated assets of the distribution company or the added value of distribution

Country	Type	Mechanism[10]	Deployment (%)
Bolivia	Not available	Not available	Not available
Guyana			
Haiti			
Nicaragua			
Surinam			
Venezuela			

As can be drawn from the table above, of the 12 countries defining a specific financing mechanism and based on public information, only 2 (Honduras and Jamaica) have established that the cost must be borne directly by the end customer. The remaining 10 countries (approximately 83% of the 12 countries with an identified financing mechanism) have defined that SM costs will be recovered through the remuneration earned by distributors. The deployment of SM is voluntary in 4 of the countries and mandatory in 2. No mandatory scheme for deployment has been found in 4 of them.

The following table shows the relationship between the definition of meter ownership and the financial mechanism defined to pay for the deployment of MI:

Table 8: Meter ownership and financing mechanisms in LAC countries

Source: Prepared by the authors

Country	Meter ownership	Financial mechanism
Argentina	Electricity distributor	Not available
Bahamas	Not available	
Barbados		
Belize		
Bolivia		
Brazil	Electricity distributor	
Chile		Remuneration - VAD
Colombia		
Costa Rica		
Ecuador		

<table>
<tr><th>Country</th><th>Meter ownership</th><th>Financial mechanism</th></tr>
<tr><td>El Salvador</td><td>Not available</td><td>Not available</td></tr>
<tr><td>Guatemala</td><td>Electricity distributor</td><td>Remuneration - VAD</td></tr>
<tr><td>Guyana</td><td rowspan="2">Not available</td><td rowspan="2">Not available</td></tr>
<tr><td>Haiti</td></tr>
<tr><td>Honduras</td><td rowspan="3">Electricity distributor</td><td rowspan="2">Client</td></tr>
<tr><td>Jamaica</td></tr>
<tr><td>Mexico</td><td rowspan="2">Not available</td></tr>
<tr><td>Nicaragua</td><td>Not available</td></tr>
<tr><td>Panama</td><td>Electricity distributor</td><td>Remuneration - VAD</td></tr>
<tr><td>Paraguay</td><td>Not available</td><td>Not available</td></tr>
<tr><td>Peru</td><td rowspan="2">Electricity distributor</td><td rowspan="2">Remuneration - VAD</td></tr>
<tr><td>Dominican Republic</td></tr>
<tr><td>Surinam</td><td>Not available</td><td>Not available</td></tr>
<tr><td>Trinidad and Tobago</td><td rowspan="2">Electricity distributor</td><td rowspan="2">Remuneration - VAD</td></tr>
<tr><td>Uruguay</td></tr>
<tr><td>Venezuela</td><td>Not available</td><td>Not available</td></tr>
</table>

As can be seen in the table above, the 10 countries that have established that the costs of SM shall be recovered through the remuneration received by electricity distributors, have generally defined that ownership of the smart meter would fall o the electricity distributor. Additionally, the 2 countries that have determined that the costs shall be borne by the end customer directly, Honduras and Jamaica, they have also established that ownership would fall on the electricity distributor. The trend in LAC countries is to allocate ownership to the electricity distributor regardless of the financial mechanism in place.

This differentiation in financing schemes can also be observed globally, although in many cases regulated mechanisms are adopted to pay for installation. The success of the scheme applied in each country will depend, among other aspects, on the extent these schemes meet the specific needs of each country, the benefits expected to be perceived by users and their perception of deployment.

To this end, a CBA for the deployment of SM in the country, as well as designing a national strategy that sets specific deployment objectives, will be key tools to determine which financing mechanism best suits each country's conditions.

Experiences and lessons learned

How SM deployment is encouraged and who is responsible for its implementation are key considerations for decision makers in government and will make success or fail the national deployment of SM. Senior government officials can decide the **degree of obligation to install smart meters**, that is, if all end customers must install smart meters or if end customers can decide to accept or refuse installation. A mandatory deployment typically has the advantage of achieving high installation cost efficiencies and will make add to the efficiency and better sizing of the associated communications infrastructure. Voluntary deployment involves addressing both technical and economic challenges, but provides an approach where the consumer has freedom of choice and, therefore, will not create potential barriers to social acceptance towards SM.

Regarding the **responsibility for installing** SM, three widespread options have typically been tried, namely electricity distributors as smart meter providers (Texas), the appearance of new regulated agents specializing in SM (France), or the retailer or electrical trader as a competitive service requirement (UK).

Another relevant aspect that should be considered in SM deployment is **financing** and who will ultimately pay the new cost. The most widespread financing schemes for SM environment technologies are financing or subsidizing by government (France), payment by electricity resellers, which has meant an increase in the final rates applied to customers (UK) or payment by the end user at a specified fee (Texas).

Latin America and the Caribbean

The region, as has been seen, has adopted SM at various degrees. Some countries have prepared or are preparing CBAs, strategic plans, and pilot projects though they may not have deployed SM massively throughout their territory. An example is Brazil where deployment is still very low. Despite this, more than half of the countries reviewed here have already started the journey to deploy SM, have prepared a CBA, have published a strategic plan considering specific SM objectives or have developed the regulatory framework to foster SM. It is also important to assess the necessary capacity to implement SM. Caribbean countries such as Trinidad and Tobago, with a small population and a medium-high level of income per capita, compared to other regional countries, have reached 94% SM penetration. The economic capacity of these countries could explain the high degree of penetration as in Trinidad and Tobago[11].

Nations also differ in regards of regulations. While some have followed the example of developed countries and have implemented new regulations to adapt to the challenges, others have adapted certain regulations that leave certain relevant aspects still undefined, such as responsibilities regarding data protection. In this sense, many LAC countries still must develop regulations that adapt to the changes that the market demands regarding SM.

The Chilean case

A particular case among LAC countries is that of Chile, which stands out for two reasons. On the one hand, it is the country with the greatest preparation for a massive deployment of smart metering: it has a CBA, has established a strategy and has carried out extensive regulatory developments on the matter, including technical regulations that define all the parameters that a smart meter must meet. On the other, the massive deployment of the entire infrastructure has not yet begun, beyond pilot projects by some distributors such as Enel, which had installed 250,000 meters in Santiago de Chile as of 2019.

It is possible that one of the reasons why this deployment has not yet started on a massive scale is the judicial process to which Law No. 21,076 of February 2019 is subject, which "modifies the General Law of Electric Services to impose on the energy distribution company the obligation to pay for the removal and replacement of the junction and meter in case the facilities are rendered useless due to force majeure" as well as other resolutions of the CNE. The law incorporates a new 139 bis article that establishes that the connection and

[11] Trinidad and Tobago, with a project defined by its electric company in 2007, has reached 94% penetration as of 2011. However, meters were required only to allow remote readings, disregarding all the functionalities that are currently required from smart meters.

the meter are elements of the distribution network and, therefore, are the property and fall under the responsibility of the concessionaire of the public distribution service or of whoever provides the distribution service.

However, due to the foregoing, and according to the electrical regulatory design of Chile, the remuneration of electrical installations carried out by electrical distribution companies - including those related to SMMC smart metering systems - are transferred to the electrical tariffs of consumers. This created great social discontent, which meant the paralysis of the deployment of smart meters, thus delaying the fulfillment of the national objective that the Government had established.

Nonetheless, voluntary installation of the new meters was decided while the country's objectives were updated. Deployment is expected to be completed by the end of 2025, with 30 % implementation in 2023 and 60% in 2024, to reach over 6 million units installed by the end of 2025.

Other regions

A) Europe

In 2009, the European Union set a goal of reaching 80% of consumers with smart meters by 2020. In its "Clean Energy Measures Package" certain measures were regularized, such as the characteristics that smart meters should feature or how to deal with the protection of data.

As a step prior to the deployment of SM and the structuring of a regulatory framework that would define it in each country, the member countries were asked to carry out a CBA to determine the feasibility of the project. However, even though the methodology to develop the CBAs was well established, no detailed CAPEX and OPEX were specified, which should be considered for the study. In this sense, not all countries considered the same CAPEX and OPEX, giving rise to disparities in CBA results.

The following table shows the result of CBAs and their date of completion in each country:

Table 9: Results of the latest CBA in EU countries
Source: European Commission (data updated to 2019) and own elaboration

Country	Result	Date
Austria	Negative	2010
Belgium*	Inconclusive	2017
Bulgaria	Negative	2013
Croatia	Positive	2017
Cyprus	Positive	2014
Czech Republic*	Negative	2016
Denmark	Positive	Not available
Estonia	Positive	2011
Finland	Positive	2008
France*	Positive	2013
Germany*	Negative	2013
Greece	Positive	2012
Hungary*	Not available[12]	2018
Ireland*	Positive	2017
Italy*	Positive	2014
Latvia*	Positive	2017
Lithuania*	Inconclusive	2018
Luxembourg*	Positive	2016
Malta	Not available	Not available
Netherlands	Positive	2010
Poland*	Positive	2014
Portugal*	Positive	2015
Romania	Positive	2012
Slovak Republic*	Inconclusive	2013
Slovenia	Positive	2014
Spain	Not available	Not available
Sweden	Positive	2015

*These countries carried out more than one CBA analysis. The result and year of the latest available are shown

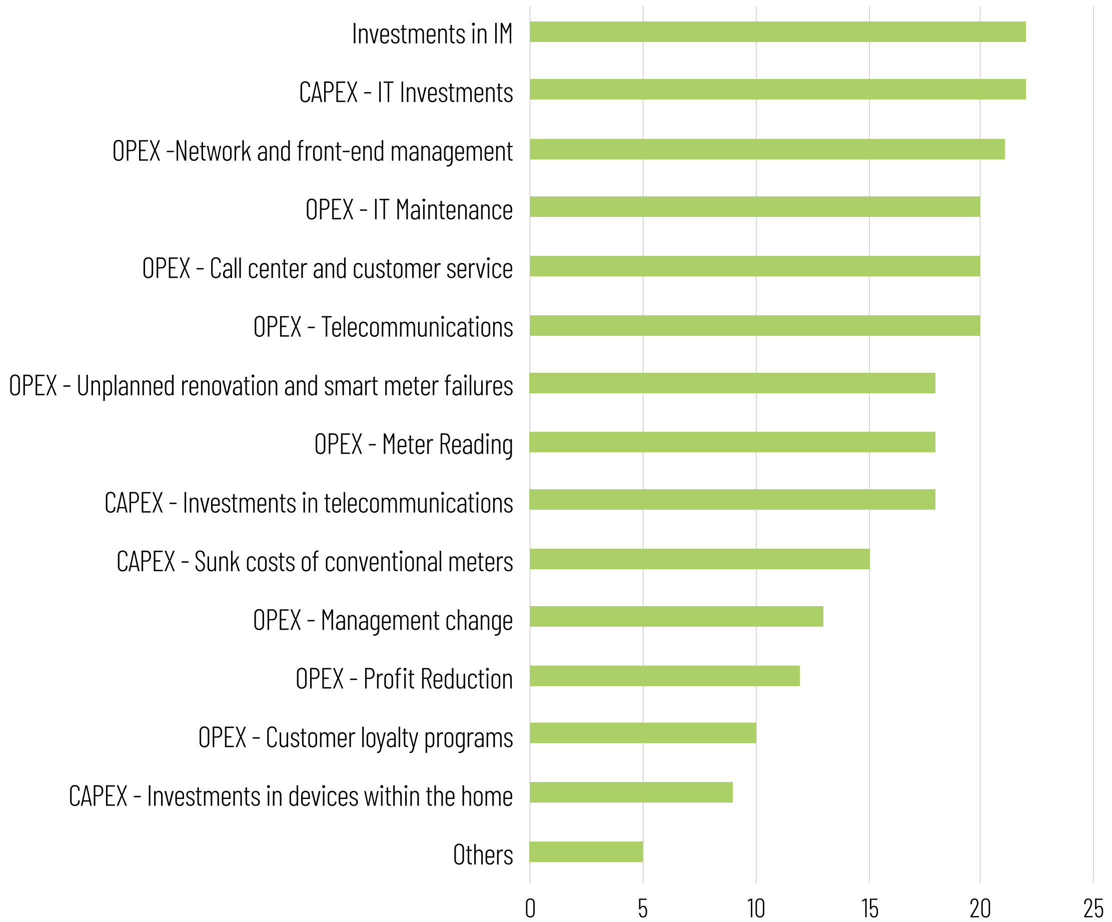
[12] According to the source of the data, Hungary performed its first CBA in 2013. The result was inconclusive. Later in 2018, it again carried out a CBA including the costs and benefits, but the result is unknown.

The table above shows CBAs are not publicly known for only two countries. However, Spain, one of these, had already begun the deployment in 2008, a year before the EU decreed its implementation. That is why no exhaustive CBA is available for that country. In addition, 17 of the 27 countries may have obtained a positive result. One of the reasons why Europe has a high degree of deployment (as mentioned earlier in this report) is the fact that many of its countries revised their initial CBAs, following the recommendation by the European Commission to review the result of CBAs every 4 years, or more frequently, in response to significant changes in the analyses assumptions and technological and market developments. More specifically, 13 of the 27 countries would have updated their CBA.

The following graph shows the typology of costs and how many countries included them in their SM CBAS.

Graph 5: Costs considered in the CBA carried out by European countries

Source: Prepared by the authors based on "Benchmarking smart metering deployment in the EU-28 (2019)[13]



[13] According to the source of the data, the costs considered in the CBA carried out for the following countries are not known: Slovenia, Finland and Denmark. Likewise, there is no CBA for Spain and Malta. In the case of Hungary, the result of the analysis is not known, but the costs and benefits in the 2018 CBA are.

Without considering the CAPEX associated with "Others", which typically includes very specific characteristics for each country, the CAPEX category related to "Investments in devices within the home", considered by 9 countries, has been the CAPEX category least considered by the countries that have performed a CBA (approximately 41% of the EU countries considered in this analysis). On the other hand, the costs associated with "Investments in SM" and with "Investments in IT" have been considered by all the countries for which information is available. It should be noted that, of the 15 detailed categories, 9 have been considered by more than 18 countries, which denotes a great homogeneity throughout the EU and a very exhaustive analysis by member countries, yielding in most cases positive results leading to a wide deployment if we compare them with LAC countries.

Likewise, in 2012, the European Commission prepared a document recommending 10 minimum functionalities that countries could consider when implementing MI systems[14]. These identified minimum functionalities are listed below:

i) Provide readings directly to the customer and to any third party designated by the consumer.

ii) Update the readings mentioned in point (i) frequently enough to allow the information to be used for energy saving purposes.

iii) Allow remote reading of meters by the operator.

iv) Provide two-way communication between the SM system and external networks for maintenance and control of the metering system.

v) Allow readings to be taken frequently enough for the information to be used for network planning.

vi) Offer an advanced rate system.

vii) Allow remote on/off control of the supply and/or flow, or power restrictions.

viii) Provide secure data communications.

ix) Prevent and detect fraud.

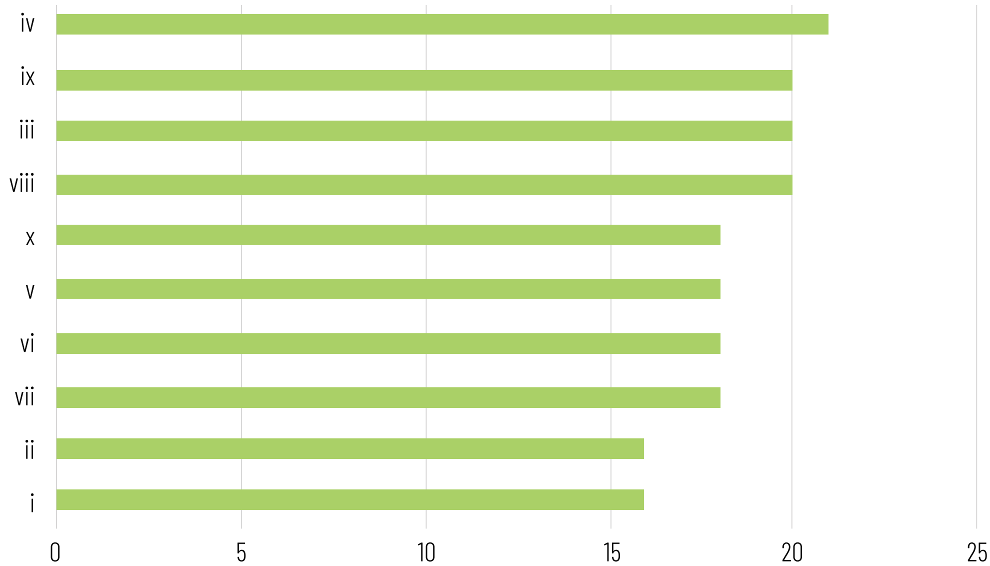
x) Provide import/export and reactive measurement.

The following graph shows the number of countries, out of the 27, have adopted these 10 recommendations. Notwithstanding the foregoing, not all the countries that have defined these functionalities have carried out a CBA, as is the case of Spain and Malta. Or on the contrary, not all the countries that have carried out a CBA took these SM functionalities into consideration, as is the case of Bulgaria, Cyprus, Denmark, Hungary and the Czech Republic.

[14] Source: 2012/148/UE: Commission Recommendation of March 9, 2012, on the preparations for the deployment of smart meter systems.

Graph 6: Technical functionalities considered by the countries of the European Union

Source: Prepared by the authors based on "Benchmarking smart metering deployment in the EU-28" (2019)[15]



Widespread adoption of homogeneous functionalities can be observed in EU countries, and approximately 16 countries have adopted all the recommended functionalities. The functionality considered by more countries is "iv) Provide two-way communication between the SM system and external networks for the maintenance and control of the metering system." Functionalities ix), iii), x) and viii) have been considered by 20 countries.

In addition, it should be noted that Europe has carried out quite exhaustive monitoring of the degree of deployment. In this sense, in 2019[16], late deployers were Greece, Romania and Hungary. At the other end, the countries that had advanced the most were Italy and Spain with more than 90% deployment and Sweden with 100% deployment. It should be noted that, in 2019, the European Commission, to review the objective of reaching 80% consumers with smart meters by 2020, approved a new package of measures to foster SM deployment in countries that have not yet achieved their goals.

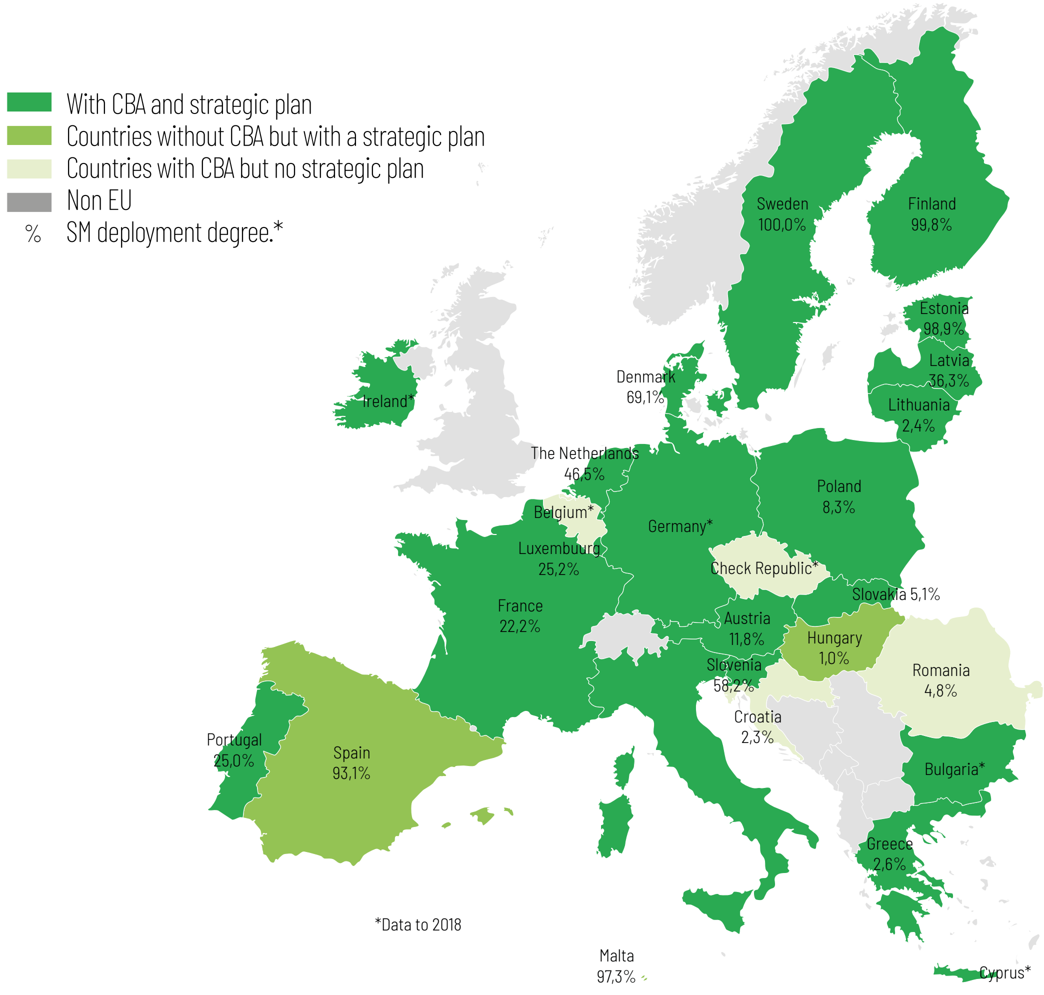
To illustrate the effort made in the EU territory in terms of SM, the degree of SM deployment presented by EU countries in 2018 is shown below, as well as those countries that had already prepared a CBA and/or a strategic plan.

[15] According to the source of the data, the functionalities of the meters considered in the CBA carried out for the following countries are not known Bulgaria, Cyprus, Denmark, Hungary and the Czech Republic.

[16] Benchmarking smart metering deployment in the EU-28 (2019).

Illustration 9: Degree of SM deployment in European countries

Source: Prepared by the authors based on Benchmarking smart metering deployment in the EU-28 (2019)[17]



The European case highlights that, although most countries have adopted strategic plans and carried out a CBA, some countries have encountered difficulties for implementation, with not so positive results, as is the case of France whose case we detail below.

C) France

The French model is very similar to the Texas model for SM implementation. In 2010, the French government published a decree[18] to encourage the deployment of smart meters and assigned responsibility for their installation to a single company[19] (Enedis), created by EDF[20], which developed and executed a program from 2015 to 2021 to achieve to modernize the electricity distribution network by replacing traditional meters by smart ones in France[21].

[17] According to the source of the data, those countries for which the degree of SM deployment is unknown have been marked "*".

[18] Decree no. 2010-1022 of August 31, 2010 on metering devices in public electricity networks in accordance with IV of article 4 of law no. 2000-108 of February 10, 2000 on modernization and development of public electricity service.

[19] Enedis, was previously called ERDF (French Electricity Distribution Grid).

[20] Électricité de France.

[21] Smarter Together - Report on deployment of Linky smart power meters in the area - D3.4.2 - Version 2.0 - 07/01/2019

The cost of the program and with it, the installation of the smart meters, was the responsibility of Enedis, financed both by EDF and European public funds[22].

At the same time, in a deliberation in December 2020, the CRE[23] approved an increase in the rates to be applied by Enedis, which would mean an increase in the annual electricity bill of consumers. This fact was perceived by consumers as a cost associated with the installation of smart meters.

During the program period, consumers had to permit the replacement of the meters in their homes, but there was no obligation to replace them, which meant a slowdown in meter replacement compared to initial goals.

In 2021, the objective of 100% replacement of meters was not reached[24], which is why the CRE in February 2022 published a new incentive regulation framework good through 2024[25], by which it is approved that those consumers who refuse installing a smart meter on their property after January 2023 will pay a higher rate including a service charge for manual meter reading. This measure aimed at achieving full deployment of smart meters in households in France despite social opposition.

B) Texas - United States

The regulatory change that led to the deployment of smart meters in Texas occurred in 2005, authorizing both the Transmision System Operator (TSO) and the Distribution System Operator (DSO) to own and operate all infrastructure associated with SM. It is important to note that competitive retail providers (marketers) were initially given this role, but the deployment of smart meters did not reach the expected massive level, so it was decided to redefine the responsibilities for the adoption of smart meters.

Regarding the financing system to support the costs of deploying smart meters, the Texas Public Service Commission[26] authorized TSOs and DSOs to include an additional cost to end customers in the monthly electricity bills. To encourage this change, the Texas Public Service Commission did not implement the mandatory installation of smart meters in homes, but it did increase the costs in the electric bill for those users who decided not to install a smart meter. These measures resulted in massive deployment of smart meters in Texas.

[22] Smarter Together - Report on deployment of Linky smart power meters in the area - D3.4.2 – Version 2.0 – 07/01/2019

[23] CRE: Commission de Régulation de l'Énergie

[24] Source: CRE https://www.cre.fr/Actualites/la-cre-definit-le-nouveau-cadre-de-regulation-du-projet-linky

[25] DELIBERATION N°2022-64: Deliberation of the Energy Regulation Commission of February 24, 2022 on the draft decision on the incentive regulatory framework for the Enedis smart meter system in the BT voltage range ≤ 36 kVA (Linky) for the period 2022-2024 and amendment decision No. 2021-13 providing for the tariff for the use of public electricity distribution networks (TURPE 6 MV-BT)

[26] PUCT: Public Utility Commission of Texas

C) United Kingdom

The UK regulatory model differs considerably from the Texas model and with it, the degree of SM deployment achieved. The United Kingdom was a member of the EU until January 2020 and therefore also committed, like the rest of the EU countries, to reach an 80% deployment of SM by 2020.

In 2012, the Department for Energy and Climate Change of the United Kingdom[27] published its SM regulation, which put the responsibility for implementation, as well as the associated cost, on energy retail agents (traders), without any economic incentives that would reduce their economic burden. This is why the United Kingdom did not reach the deployment target initially set for 2020 and delayed that target until 2024.

The Office of Gas and Electricity Markets of the United Kingdom[28] fined retailers that failed to meet deployment objectives. In addition, a measure that was carried out to promote the deployment of residential smart meters was to reduce electricity rates for those users who decided to install SM. However, this measure did not reach the expected result because the associated cost for installing meters was transferred to the end user by the marketing companies.

[27] DECC: Department of Energy & Climate Change
[28] OFGEM: The Office of Gas and Electricity Markets

Recommendations to establish a smart metering regulatory framework

When talking about smart grids, it is common to relate them to SM and specifically to smart meters. Installing **this type of meter is essential to build a smart grid** in its initial stages, making it strategically possible to typically have **accessible, reliable, and harmonized data throughout the value chain** of each country's electrical system.

SM **is a key strategic element to build decarbonized, digitized and electrified economies,** thanks to its multiple benefits. SM facilitates realizing **construction efficiencies and the operation and maintenance of electrical networks,** increasing efficiencies in energy consumption, greater competitiveness in the energy sector facilitating the development of new energy services and, of course, empowering final consumers, by providing consumers with access to their electricity data and allowing their more active participation in the electricity market.

Likewise, it is important to note that **smart meters themselves are one of the main components of a broader set of solutions for SM,** in which their functions are integrated, and which need to be accompanied by advanced metering infrastructures (AMI) and other energy management and information systems. Defining SM design, implementation and responsibilities are key to attaining the benefits of SM and, consequently, the digitization of electricity networks. That is why national **regulators play a fundamental role in the design of a regulatory framework that effectively encourages deployment and realizing quantifiable benefits** for the electricity system, stakeholders and society at large. To this end, the involvement and collaboration of all public and private agents will be key to guaranteeing the success of SM deployment.

To encourage deployment of smart metering and taking into account the study of the experiences of LAC countries in deploying SM, examining other international experiences and the recommendations of the regulatory authorities of the countries that have started deployment, **is advisable** before starting the deployment on a massive scale, **to carry out a CBA that studies economic feasibility,** considering the entire technological ecosystem of SM, **to define a national strategy that sets specific deployment objectives, as well as structuring a robust regulatory environment that encourages investment and provides security** to the agents in the electricity sector.

A series of **recommendations** for **energy regulators in LAC are detailed below, in relation to those aspects that are critical in a massive SM deployment process, which could encourage and maximize the success of this process:**

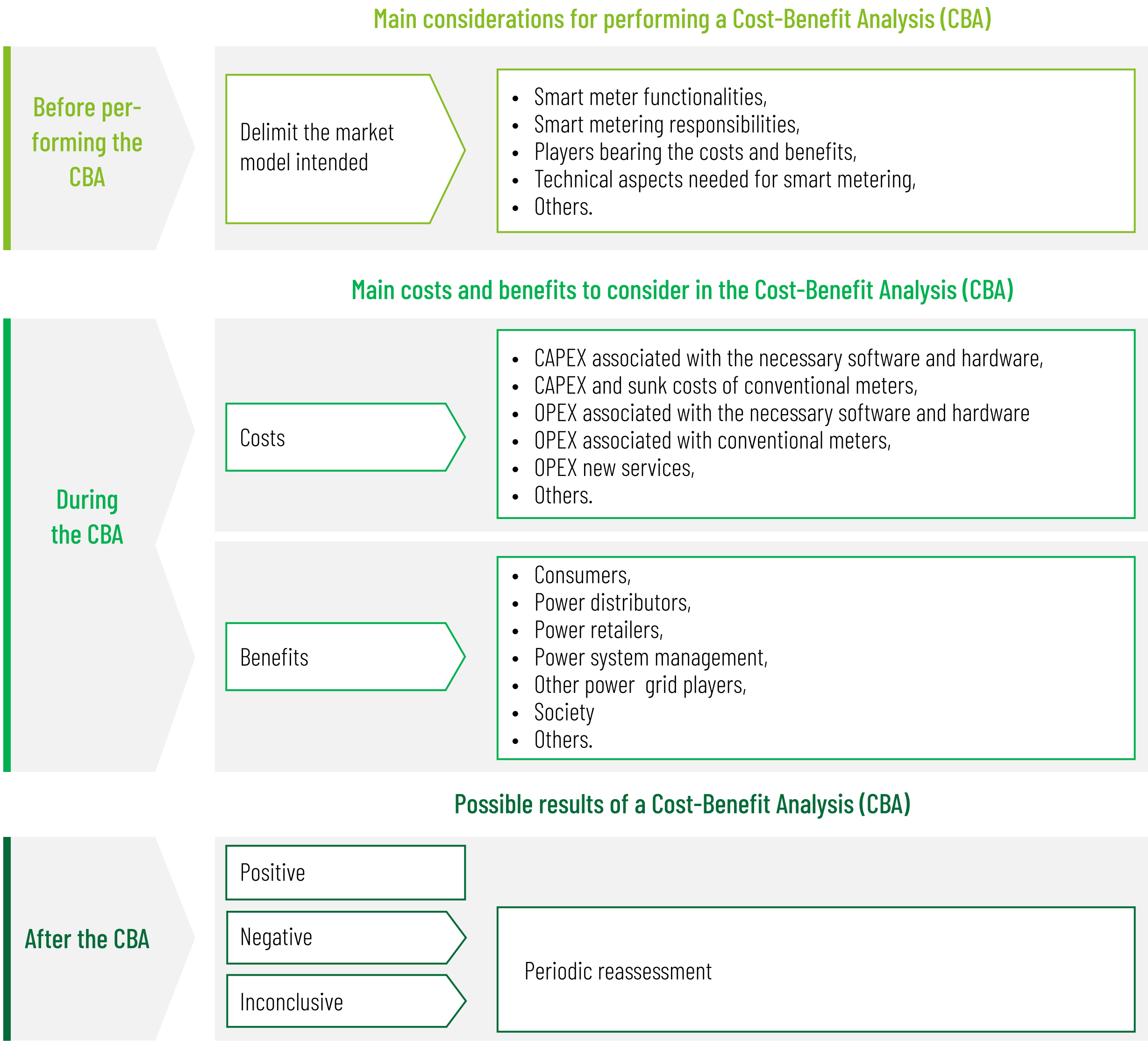
1. In connection with a Cost-Benefit Analysis (CBA)

Most LAC countries have not yet started a massive SM deployment, as shown in the review of SM in LAC. To launch this process, these countries could commit **to perform a CBA that examines the technical and economic feasibility of deploying SM in each country and evaluate whether or not its deployment is appropriate.** By way of complement, in those cases where the result of the CBA is negative or inconclusive, **it would be recommended to carry out a periodic reassessment, suggesting periods of 4 years or less** when there are relevant changes in the initial conditions considered in the CBA carried out previously, to encourage SM in the future, but as long as there is a positive techno-economic viability of the SM deployment, which provides security to the agents involved.

The methodology for a CBA is essential to obtain robust and reliable results to prepare such a relevant decision. The CBAs already carried out by LAC countries have enforced very different methodologies and, on occasions, methodologies that may not fully capture the economic, technological and social reality of each country.

Given the importance of performing a CBA and, consequently, its result in the decision-making of regulators and government agents on the deployment of SM, it is **recommended to adopt a robust methodology that incorporates the best practices,** facilitating in turn, the incorporation of common aspects in countries of the same region to permit their standardization. The following illustration details some of the main aspects to consider in the design of a robust SM CBA.

Illustration 10: Relevant aspects to consider for a CBA (non-exhaustive)
Source: Prepared by the authors



In this sense, **the CBA must be carried out considering the entire value chain,** considering from electrical distributors to other agents involved such as electricity retailers, other electricity utilities, electricity generators, electricity consumers, etc.

Delimiting **the SM market model provides focus to this process,** to guarantee that all the expected costs and benefits are being adequately considered in the model. At this stage the technical solution to be adopted must be clearly defined, considering, among other aspects, **the type of data that is intended to be obtained and the functionalities that are intended to be incorporated into the SM system, as well as identifying the responsibilities** for the different process players, data security, etc. This **will allow a more precise identification and quantification of the costs and benefits related to this process.** In this way, a deployment with a greater granularity of the accessible data and a greater degree of functionalities can enable greater benefits, although this deployment will be more expensive. The **definition of different deployment scenarios can also allow the identification of an ideal deployment model that will be more suitable** to each country. In the same sense, **the consideration of costs and benefits for a longer period will allow the obtaining of a more robust result.**

Some of the main costs and benefits that are typically considered in an analysis of this type are identified below, considering the best international practices in the matter.

1. **Costs typically considered in a CBA** are: (i) CAPEX associated with smart meters, their installation, communications, the necessary advanced metering infrastructure and IT systems; (ii) OPEX associated with the operation, maintenance and replacement of the necessary equipment for SM, and (iii) Costs associated with the installation and operation of the infrastructures for communication between electricity sector players and the infrastructures necessary to manage SM data.

2. **Relevant benefits that are recommended to be considered in an SM CBA throughout the entire value chain** are:

   (i) the economic savings for the electricity distributor, since SM allows them to have more information on demand from power distribution, facilitating measures that optimize the operation and maintenance costs of electrical networks, as well as those associated with new investments;

   (ii) the energy savings and, therefore, economic savings, for the final consumer, who will have access to their historical energy consumption and even in real time, the possibility of defining hourly rates, adoption of demand management or reduced consumption mechanisms at times of greater grid congestion, for example;

   (iii) the location of technical and non-technical losses through SM, which will entail both energy and economic savings for the grid and therefore for consumers;

   (iv) social benefits due to a smaller carbon footprint and contribution to the energy transition, derived from the optimization of final consumption and reduction of electrical losses, as well as the contribution to the development of new renewable generation from the introduction of mechanisms that encourage self-consumption/self-generation or energy communities;

   v) the benefits for the most vulnerable consumers derived from the fight against energy poverty, by enabling access to information that may allow the identification and implementation of measures to fight energy poverty;

(vi) other benefits related to the development of a more competitive electricity market, with a higher quality of service for the consumer and more competitive pricing, as well as,

(vii) an empowered energy consumer who can actively participate in the grid, leaving behind their traditional passive role.

A CBA that considers the technical-economic feasibility of deploying smart metering **is essential to define the basis for a viable regulatory framework on SM,** while addressing the particularities of each country. As a priority, the analysis shall consider all the possible costs and benefits derived from deploying SM, considering the functionalities and solutions that will be offered and each country's local context.

2. In relation to national SM strategies

Undoubtedly, the definition of a national strategy is a key element in a transition of this type. The definition and identification of specific objectives, support measures, activities, capacities and tactics to achieve the massive deployment of SM within the framework of a national strategy provides clarity and greater security in a process that implies that certain agents assume risks and invest.

Defining a national strategy justifies the mobilization of efforts and resources, providing security and structuring support measures, encouraging investment in this technology by the agents involved in the SM field.

A country's deployment of SM not only implies the introduction of a new technology in the context of the electrical system with numerous technological, social and economic challenges to be addressed, but also a great opportunity to materialize certain benefits for the electrical system itself, its consumers and society at large, which must be considered in the design of a robust deployment strategy.

An SM strategy must consider aspects typically contemplated in technological deployment strategies in the electricity system, such as the design of the business model, the lines of action to be executed, the opportunities and expected benefits or the mechanisms for financing, among others, although it is recommended that this strategy specifically address some aspects that have typically been barriers to the introduction of SM in some countries, such as:

- **Design of a strategy agreed upon with the main agents.**

  The strategy must draw lines of action to create an appropriate regulatory framework, the technologies to be adopted, the responsibilities of the different agents, the appearance of new agents, their governance, etc. The general consensus with all the agents will be essential to reach an optimal model for the country and responding to the needs of the different agents.

  To this end, it is recommended that the person(s) charged with defining the national strategy hold dissemination and socialization sessions involving the main stakeholders, in order to define a robust and shared strategy, to define the main areas of action of each agent and to consider possible projects these agents may promote, as well as other suggestions or recommendations identified along the way.

Building consensus among and garnering support of all stakeholders, including end consumers, is a fundamental aspect to guarantee the success of the national SM strategy.

The **main agents interested in a deployment of this type and the areas of action where they are traditionally operating** are identified below, considering the best existing international practices.

1. **The national government** sets the objectives and defines the roles and responsibilities for the national deployment of SM. In addition, once deployment has started, it monitors and oversees the accomplishment of the established objectives, as well as the reaction of the users involved in deployment. Monitoring and control will ensure that SM objectives are achieved, both in the short and long term. Additionally, the government also warns regulators of the need to establish rules and regulations that guarantee the protection of consumers and, once established, carry out a disclosure process to give greater support to the deployment of SM before final consumers.

2. **The regulatory body** is responsible for guaranteeing consumers protection and ensuring that energy providers meet electricity quality and continuity standards for electricity supply, in addition to introducing new regulations to facilitate deployment and capture the expected benefits (for example, new rates resulting from more frequent consumption data). Additionally, it also typically supports the dissemination function to electricity distributors and to retailers, energy managers and consumers to encourage SM deployment.

3. **Electrical distributors and retailers** are typically responsible for installing smart meters For this reason, they must meet the rules and regulations set forth by the regulator regarding the accuracy of the data collected, access to data or data security, among other aspects.

4. **Communications and data management companies** provide the communications infrastructure that manages SM data with the ultimate goal of guaranteeing electricity sector agents adequate immediate, accessible, accurate and granular data.

5. **Other electricity service companies may join** the value chain to provide energy services based on the new information available as a result of SM implementation, thus helping to create a more competitive market. To do this, they must have access to information, while safeguarding the confidentiality of consumers and data. Typically, this information can be public information or private information provided by end consumers.

6. **Electricity consumers** will fully or partially pay the cost of deployment, so they must be guaranteed a series of functionalities and rights so that they can obtain sufficient benefits to generate a positive return on investments, which in addition shall give them security.

- **Place the consumer center stage**

  The adoption of a model of this type typically has a very high initial cost for the electrical system, which will end up being borne by consumers. That is why the benefits must be tangible for them, allowing them to defray the costs in the future and receive a higher quality electrical service, but at the same time allowing their empowerment with active participation in the electrical sector, which will result in a more sustainable electrical system and a lower electricity bill.

- **Promote confidence in aspects related to security, confidentiality and data protection** in order to provide security regarding the processes of capturing, communicating and using consumer data.

Schemes where the ownership of the data belongs to the final consumer, must include specific confidentiality and security regulations and protocols to guarantee end users the adequate protection of their personal information, and thus bolster consumer confidence.

- **Avoid consumers perception of a higher electricity bill.**

  It **is recommended to give visibility to the remuneration mechanism that is defined to finance the deployment of SM and how these costs will be recovered**, as well as the development of a regulatory framework that guarantees implementation, the rights of consumers and the realization of the expected benefits.

  To avoid this perception by consumers, it is recommended to **inform consumers about the direct and indirect energy and economic benefits, quantifiable or not**, identified in the CBA, which they will be able to enjoy as a result of the implementation of SM, **and that would allow their empowerment and active participation in the electricity market**. To guarantee the above, it is recommended to assure non-discriminatory access to these benefits to all electricity consumers.

- **Avoid the perception by the population of adverse health consequences derived from the electrical components of SM.**

  It is recommended to inform on the existence of existing general electronic technologies legislation in each country, where SM can be included, as well as the new developments planned in each country to provide greater security to users in terms of their health or other aspects.

  Agents and, of course, consumers must be aware that the SM technology will abide by strict safety and quality standards and will be subject to oversight and controls by relevant agencies, to ensure compliance.

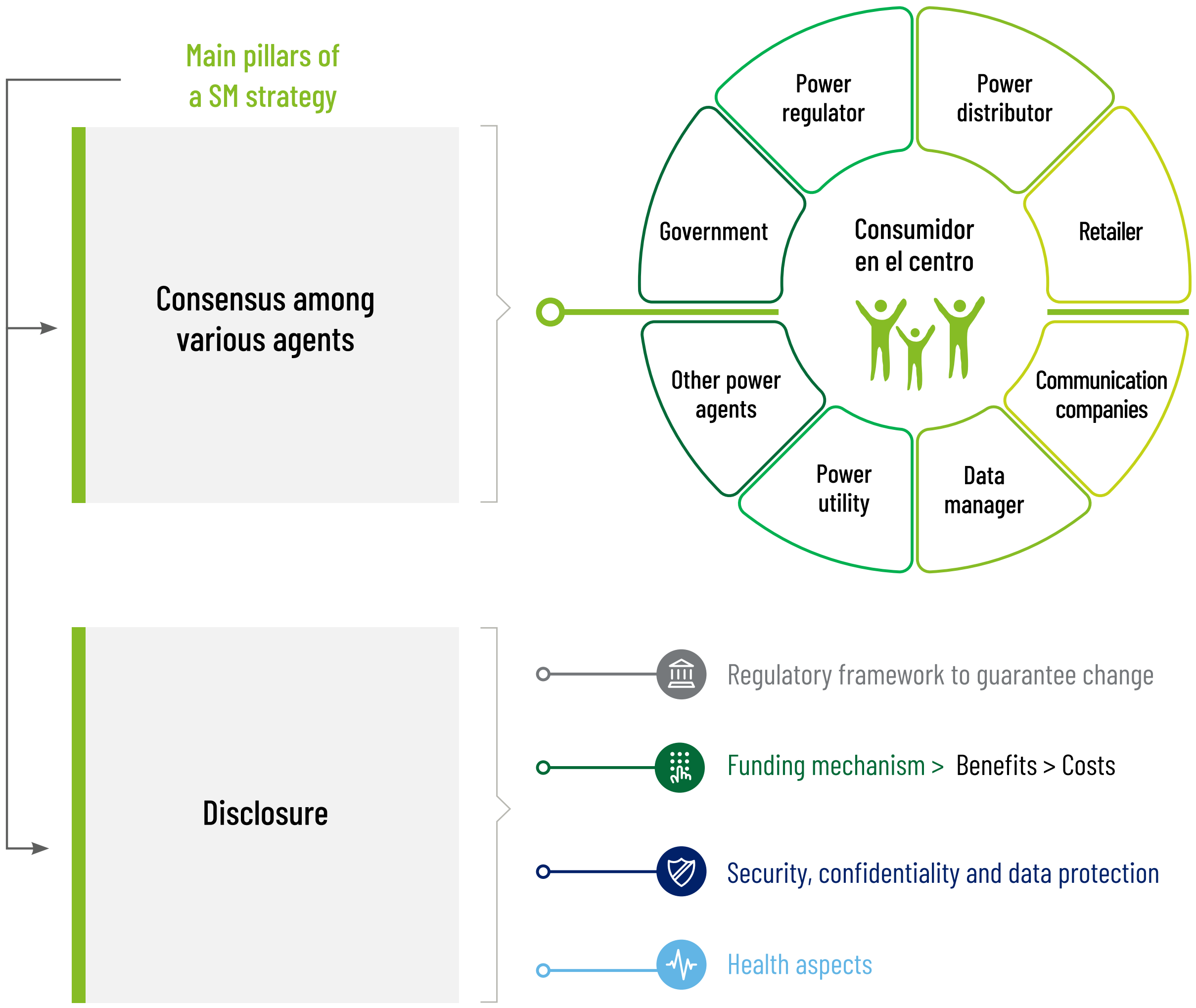
- **Prioritize dissemination through specific communication campaigns, especially among consumers.**

  Despite all the efforts for successful SM deployment, **social approval must be prioritized in the journey towards massive SM deployment.** Dissemination is required to ensure end users are informed about the benefits of MI deployment and the functionalities that its installation incorporates, both on the grid and for users, and address users' concerns around SM. Campaigns **(whether public, private or both) that promote SM deployment may raise consumer awareness and minimize social discontent about the deployment of advanced measuring systems.**

  A recommendation is made to examine **end consumers' main concerns peculiar to each country and that may trigger social discontent toward SM while adopting measures to fence or respond to them, some of which have** been identified above.

Illustration 11: Some fundamental aspects in the design of a national SM strategy (non-exhaustive)

Source: Prepared by the authors



The design of a consensus-based national strategy that places the consumer center stage, with dissemination campaigns to delimit or respond to the uncertainties of consumers and other relevant agents regarding SM will provide greater guarantees for the success of SM deployment.

3. Regulatory mechanisms to encourage SM

As observed in the analysis of the deployment of SM carried out in LAC countries, the structuring of regulatory schemes has been diverse throughout the region, although it has been possible to identify a progressive and diverse incorporation into the regulatory frameworks in several countries, with different orientations in relation to SM, elements such as **the assignment of functions and responsibilities to the different agents, principles of remuneration of costs incurred and the definition of technical functionalities and non-technical ones associated with smart meters,** among other fundamental elements for the development of a robust SM regulatory framework.

Below are certain **critical aspects that must be considered in the development of a regulatory framework that allows encouraging deployment of SM:**

- In those models in which it is decided to regulate a **remuneration associated for SM,** the following must be defined:

    1. **The regulatory mechanism to be established for cost recovery.** A specific rate could typically be established for recovery through the distribution company's regulated asset base or distribution value added. Although any option guarantees recovery, a specific rate adds transparency to the process, as the consumer can more easily identify the cost that is passed on for this process on their electricity bill. In any case, it is recommended that the contribution by consumers be made under a scheme of transparency and non-discrimination.

    2. **The type of costs that are recoverable** by the agents and therefore will be borne by the consumer. Specific components of CAPEX or others associated with OPEX could be identified. For OPEX, both additional OPEX could be identified to those already incurred in the measurement tasks or efficiencies derived from the digitization of the readings, among others.

    3. **The conditions that the distributors or agents in charge of the deployment must meet to receive the rate or remuneration associated with SM.** Sometimes objectives are established to improve the performance of the quality of service.

The following illustration details the main aspects to consider in the remuneration design for SM.

Illustration 12: Main elements of a remuneration scheme for SM (non-exhaustive)
Source: Prepared by the authors

Main aspects to be considered by the regulatory model

1 Typical remuneration mechanisms defined to recover the costs associated with smart metering

- Regulated Asset Base (RAB)
- Specific rates

2 Components of the smart meter CAPEX payable by system

- Investments in smart meters
- Investments in software (IT)
- Investments in hardware (IT)
- Investments in telecommunications
- Investments in in-home devices
- Sunkecosts of conventional meters

3 Conditions to earn remuneration associated with the CAPEX

- It is not necessary to meet any condition, only installation
- Improve the quality of service re power outages
- CAPEX optimization connected to new investments
- Other conditions

4 Components of the smart meter OPEX payable by system

- No aspect included
- The additional OPEX related to the new CAPEX is remunerated
- The OPEX associated with the meters is reduced, derived from reducing costs related to readings or other factors

- **Regulation of responsibilities of the different SM agents.**

  SM implies assigning responsibilities for emerging functions and activities among the different agents involved. The main responsibilities that must be regulated can be seen observed below:

Illustration 13: Main SM responsibilities to regulate
Source: Prepared by the authors

The responsibility to install and own meters, depending on the model, may fall on the distributor, the retailer, the consumer or even a third party.

Likewise, the responsibilities in relation to the data (access, reading, storage, treatment and transmission) usually fall on the distributors or specific designated agents.

The installation and ownership of in-home devices is typically paid by consumers, although there are countries where other agents carry out such deployment.

- **Specifications of smart meter functionalities**

  One of the main issues, beyond the technical functionalities that must be guaranteed for SM, is the security and privacy of data and its communications. In particular, it is recommended to adopt a principle of proportionality to guarantee the security of the adopted SM system and, consequently, an adequate treatment of the data collected. The costs to assure data security must be proportional across the SM installation, so that they do not impose an additional financial burden in the face of a massive nationwide deployment. It is recommended to incorporate the following data functionalities in smart meters:

  1. Smart meters **should provide information** about consumption to end users, both historical and real-time, with sufficient granularity of information for the objectives sought (for example, quarter-hour, hourly, daily information), etc.).

  2. **Remote measurement systems** must be implemented by the agents responsible for the readings and remote management, in order to maximize the benefits derived from their implementation.

  3. **To guarantee the interoperability** of SM and the associated devices, it is not only recommended to comply with technical measurement capabilities, to provide information, data, energy supply contracts and price options to the users, but also on other aspects related to power supply, such as the remote changes on the maximum demand admitted or remote on / off supply, or even connecting to any smart home device. To guarantee interoperability, it is recommended to set forth common criteria for the type of smart meters to be installed and the communication protocols for the SM system.

  4. Smart meters should make it possible to **send information about the electricity** generated by prosumers, as well as that which is fed into the network, guaranteeing bidirectional communications between agents.

5. The **measurement of reactive energy** for certain types of customers may be recommended.

6. Smart meters should comply with the **privacy, data protection and security regulations** of each country.

7. **Fraud detection and prevention protection protocols must be established.** Smart meters are vulnerable and are subject to increasingly sophisticated malpractices, which is why regulations must include protocols to mitigate these vulnerabilities.

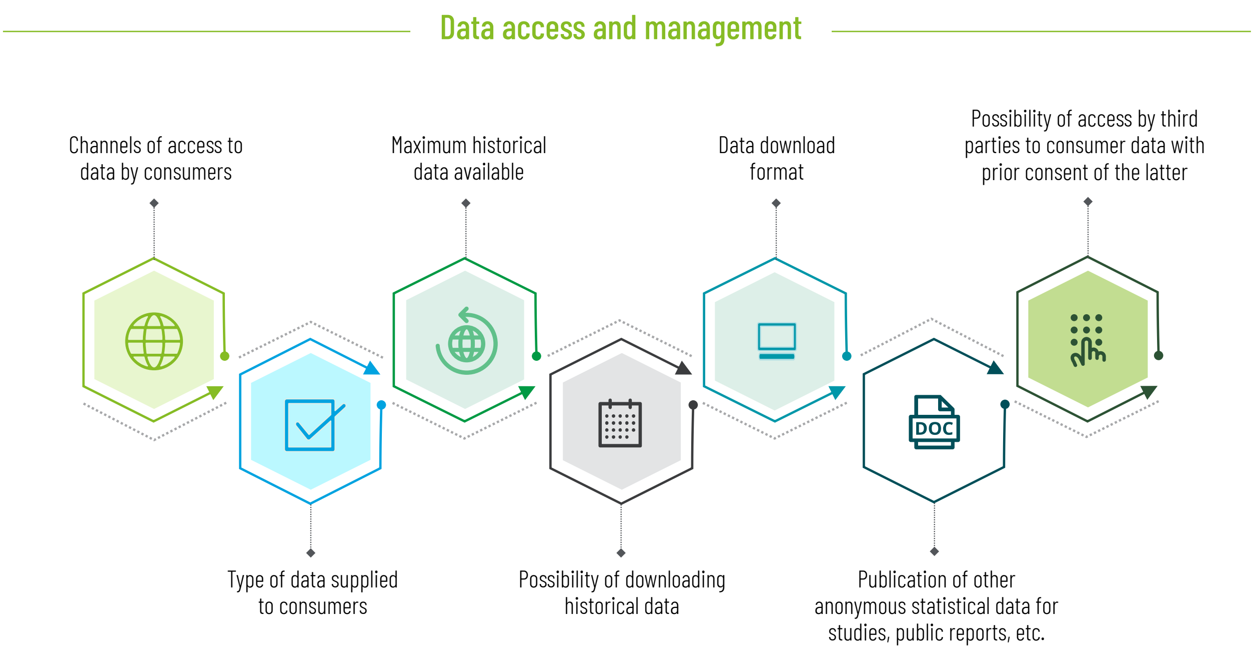
8. The data from smart meters is recommended to be the **property of consumers,** and may be transmitted to third parties, both for their management and for their analysis with the prior consent of the users.

- **Data access and management**

The following illustration details some of the main aspects to regulate in relation to data access and management.

Illustration 14: Main aspects to regulate regarding data access and management

Source: Prepared by the authors



In general terms, it is recommended to guarantee easy access, with sufficiently detailed information that is useful for decision-making.

A clear regulatory framework is required that protects the privacy of information and also regulates the conditions of access, both for distribution companies and for other agents and traders who can offer attractive energy products and services.

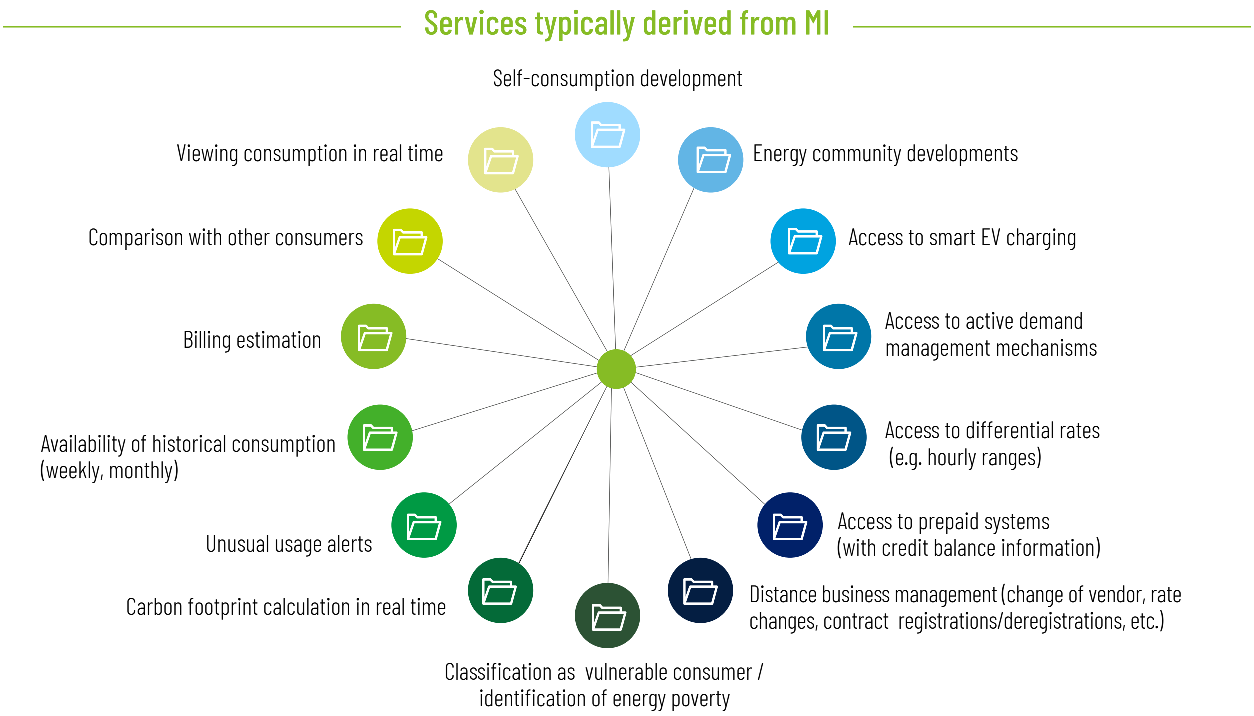
- **It is recommended to establish a regulatory framework that allows the development of new SM services.**

Based on the new data that it makes available to the different agents and new functionalities introduced in the electrical system, SM lays the foundations to build new ecosystems and business models, which will allow to provide new electricity services to consumers. SM allows new mechanisms for managing active demand, the development of energy communities, the development of self-consumption, new more efficient rate systems, more satisfactory commercial service for the consumer, etc., with a new model where the consumer is empowered and active in decision-making. However, all these developments must be accompanied by specific enabling regulation.

Below are some of the main services that are typically generated around SM and should be considered in new regulatory developments to maximize the benefits of this change:

Illustration 15: Main emerging services created by SM

Source: Prepared by the authors



The regulatory framework on smart metering must define elements intrinsic to SM, such as its financing scheme, the responsibilities and functionalities associated with SM or the access and security scheme on the information generated, to other aspects related to future services that can be established around MI and that will allow the development of new business models. The regulation of innovative business models, such as SM, is a great challenge for regulators that must be adapted to the needs and peculiarities of each country.

4. Recommendations on regulatory innovation mechanisms

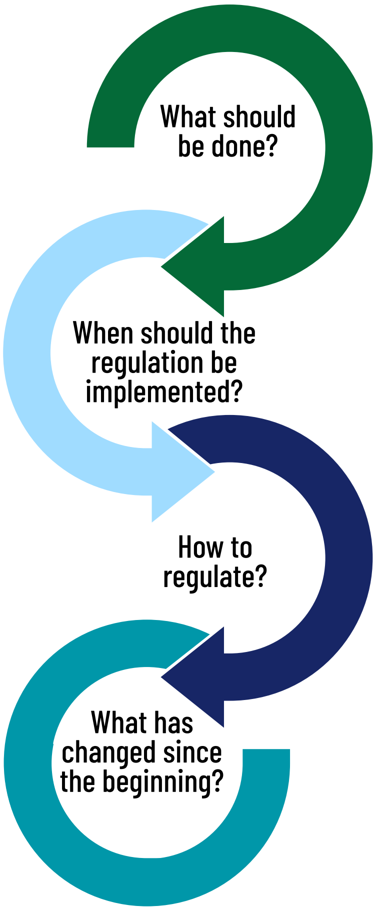
Technological advances, such as those related to digitization and, specifically, grid SM, pose a great challenge to regulators and governments of different countries. In general, **to achieve success in developing innovation, it is necessary to overcome various existing barriers,** technological, social, market barriers, the internal barriers of the organizations and those of a regulatory nature, **as well as knowing the need for regulation around a given technological introduction.**

On most occasions, regulatory developments lag technological innovations, which can lead to inefficient regulatory frameworks that send inappropriate signals to system players, making it necessary to review these frameworks on a recurring basis. This logically generates inefficiencies and hinders the development of markets. The great challenge is to be able to define a new, flexible regulatory framework that will encourage new business models and technologies such as SM, and foster a profitable innovative process, with scalable results for future developments.

To overcome these constraints and promote grid digitization, it is **necessary to review and introduce changes in the current regulations to provide a sufficient and coherent remuneration for the services and functionalities that are requested from a digitized network** and with it, create a regulatory environment for SM acceptable to all players involved, in addition to considering this digitization process as an attractive investment opportunity.

When it comes to developing a reliable and effective regulatory model for SM, regulators must respond to various questions:

Illustration 16: Steps to build a regulatory model
Source: Prepared by the authors



What should be done?

Phase 1: Pre-regulation

It is necessary to develop a review of the status of the existing regulation. In this analysis, the agents involved and the areas of convergence with other previous regulations or other transversal regulations of other sectors must be identified, carrying out an analysis of the regulatory ecosystem, with a holistic approach.

A retrospective vision often provides lessons about possible options for regulation, identification of regulatory gaps and successful and failed mechanisms.

When should the regulation be implemented?

Phase 2: Regulatory period

Choosing the right time to launch a new regulation is essential for proper development. This moment must be chosen carefully so that it is neither too soon nor too late.

Excessively early regulation may be premature in terms of the information available about the regulated event, without sufficient knowledge gained, while agents may find it difficult to adapt to the regulatory environment. Late regulation may mean that events that should have been regulated escape from the regulatory sphere (with possible adverse consequences for competition, safety, quality, etc.).

To this end regulators must be aware of and actively participate in technological innovation processes, allowing for a more agile and flexible regulatory model.

How to regulate?

Phase 3: Regulatory approach

The main reasons for regulating an activity include improving the quality of life, ensuring the protection of citizens, increasing market competition and reducing externalities.

It is essential to establish the importance of each of these elements to determine the type of regulatory model to be implemented, especially in the face of such disruptive changes as the introduction of SM.

Regulatory approaches cover a broad spectrum, depending on the importance of the regulated event, from strong and strict regulation to light regulation or even deregulation.

What has changed since the beginning?

Phase 4: Periodic review

Ongoing technological improvements in SM, as well as advanced business models make regulation gradually obsolete. For this reason, a period must be established for partial parameter reviews and for the entire regulatory structure.

Most Common Regulatory Practices

The regulatory principles presented below answer the questions of "when to regulate" and "how to regulate". In addition, the different principles establish the foundations for various points of view when it comes to understanding the process of developing the regulatory methodology. The most common practices are shown below[30].

[30] Source: The future of regulation. Deloitte

Table 10: Regulatory principles to understand the process of elaboration of the regulatory methodology
Source: Prepared by the authors

1	Adaptive regulation	A dynamic regulation is established, which evolves based on changes in the regulated environment, with a greater number of revisions and iterations, as required, instead of unchanging regulations for long periods.
2	Regulatory sandboxes	Tests, trials and prototypes help to create safe environments that allow innovation. The regulator and public and private agents participate in the trials.
3	Results-based regulation	It focuses on goals, leaving agents more flexibility on how to achieve those goals.
4	Specific risk regulation	Regulation is not general, but rather, based on detailed analysis, adopts a more segmented approach.
5	Collaborative regulation	It allows the participation of a greater number of agents in developing the standard, favoring a more inclusive regulation.

Sandboxes as regulatory innovation mechanisms

Since innovators typically lack opportunities and mechanisms to **develop and reproduce new solutions in real contexts**, an experimental space is needed to test new goods, services and business models in a real environment without enforcing some of the usual rules and regulations. **Sandboxes create safe spaces for stakeholders to test their energy solutions in a controlled environment, without the usual regulatory conditions.** Certain security measures are established to minimize the risk to final consumers and the grid, by limiting the test period and number of consumers, as applicable. Finally, **sandboxes seek to understand if the regulation should change permanently,** since the exemptions that can be granted within the sandbox will in most cases be related to the innovative project and limited in the time.

Regulatory sandboxes require the coordination and combination of multiple complementary policy actions. In particular, the incorporation of research and innovation instruments (for example, public financing of projects), with legislative measures (for example, experimental clauses), together with innovation-oriented regulatory bodies and bodies involved in energy policy (government and other entities).

In this way, regulatory innovation mechanisms such as regulatory sandboxes highlight the importance of the following considerations: i) **regulatory innovation is essential to match the benefits of new technological advances with the requirements of the market and society, and ii) innovative processes must be executed harmoniously in the regulatory, technological and business spheres.**

Consequently, energy and innovation policies, such as SM, must go hand in hand with complementary actions that serve as a multi-sector link and allow the transfer of knowledge between stakeholders.

Regulatory **sandboxes could play a potentially relevant role in SM,** as tools to facilitate innovation by allowing companies to test new ideas in controlled and safe environments, minimizing risks, **a very interesting way to develop new innovative SM-related services currently not possible in the existing regulatory framework.**

Bibliography and reference regulations

Argentina

- Inter-American Development Bank (IDB). January, 2017. Energy Dossier – Argentina.
- BNamericas. Visited September 30, 2022. Spyglass: "Smart meters in Latin America ". Available at:
https://www.bnamericas.com/es/reportajes/bajo-la-lupa-los-medidores-inteligentes-en-america-latina
- Wholesale Electricity Market Administration Company (CAMMESA). Visited September 30, 2022. Application for Incorporation of Large Users to the MEM. Available at:
https://fadmem.cammesa.com/fadmem-fe/instruccionesFADMEM.html
- Edesur. Visited September 30, 2022. Current rates. Available at:
https://www.edesur.com.ar/tarifas-cuadro-tarifario/
- Edesur. Visited September 30, 2022. Online procedures. Available at:
https://www.edesur.com.ar/servicios-al-cliente/tramites-online/
- Edesur. September, 2016. Smart Metering, the drive towards Smart Grids – Annex 3. Available at:
https://www.argentina.gob.ar/sites/default/files/rti-edesur-233342_-_plan_de_inversion_plurianual_para_las_redes_de_alta_media_y_baja_tension_-_anexo_iii.pdf
- National Electricity Regulatory Entity (Argentina). Resolution ENRE 0059/1993. Official Gazette No. 27.783 December 10, 1993.
- Federation of Electricity and Public Services Cooperatives of the Province of Buenos Aires Ltda. (FEDECOBA), Cooperatives of the Americas (Region of the International Cooperative Alliance). 2019. Contribution of Argentine electric cooperatives to development objectives. Available at:
https://www.aciamericas.coop/xxiconferencia/wp-content/uploads/2019/12/01_%C3%81ngel-Echarren_FEDECOBA.pdf
- Law Nº 24.065, Electric Power Regime.
- Ministry of Productive Development. RESOL-2022-380-APN-SCI#MDP April 12, 2022.
- Ministry of Economy (Argentina). Visited September 30, 2022. Demand for Electricity MWh (Tariff Category). Available at:
https://www.argentina.gob.ar/economia/energia/planeamiento-energetico/panel-de-indicadores/panel-de-indicadores-demanda-interna/superset-demanda-de-energia-electrica-mwh-categoria-tarifaria
- Ministry of Economy (Argentina). Visited September 30, 2022. Distributors currently enrolled in the public access digital platform by jurisdiction. Available at:
https://www.argentina.gob.ar/economia/energia/generacion-distribuida/distribuidores-actualmente-inscriptos-en-la-plataforma

- Ministry of Economy. April, 2020. Press release "Prepaid meters: new provisions that guarantee access to electricity". Available at: https://www.argentina.gob.ar/noticias/medidores-prepagos-nuevas-disposiciones-que-garantizan-el-acceso-la-energia-electrica
- Ministry of Production and Labor. Technical and Metrological Regulation for Alternating Current Electric Energy Meters – Annex.
- Resolution 247/2019 of the Productive Development Ministry. RESOL-2019-247-APN-SCI#MPYT.
- Resolution 247/2019 of the Productive Development Ministry. RESOL-2022-380-APN-SCI#MDP.
- Secretariat of Energy. Visited September 30, 2022. Introduction to the five-year period 1991-1995. Available at: https://www.energia.gob.ar/contenidos/verpagina.php?idpagina=3583

Bahamas

- Ministry of the Environment and Housing, Ministry of Works & Urban Development. 2013. The Bahamas National Energy Policy 2013 – 2033.
- Utilities Regulation & Competition Authority. Visited September 30, 2022. Register of Licences. Available at:

  https://www.urcabahamas.bs/wp-content/uploads/2022/05/ES-Register-of-Licensees-rev-220502.pdf
- WorldData. Visited September 30, 2022. Energy consumption in the Bahamas. Available at: https://www.worlddata.info/america/bahamas/energy-consumption.php

Barbados

- IDB. August 2016. Achieving Sustainable Energy in Barbados - Energy Dossier.
- Fair Trading Commission (Barbados). May 2021. Determination of Standards of Service for the Barbados Light & Power Company Limited (BL&P).
- Barbados Government of Energy. Visited September 30, 2022. Visualizations for Energy Consumption by Sector, per Year, report. Available at: https://energy.gov.bb/our-publications/data/#1634662682100-d4530b03-e70b
- Ministry of Energy and Water Resources (Barbados). January 2020. Barbados National Energy Policy.

- The Barbados Light & Power Co. Ltd. May 2017. Pursuant to Section 16 of the Utilities Regulation Act Cap. 282 of the Laws of Barbados.
- The Barbados Light & Power Co. Ltd. Visited September 30, 2022. The Advanced Metering Infrastructure Project. Available at: https://www.blpc.com.bb/index.php/company/our-projects/the-ami-project

Belize

- Belize Electricity Limited. 2021. Rate Schedule approved by the Public Utilities Commission (PUC) for electricity rates in Belize, for the period July 1, 2021 to June 30, 2024.
- Energy Unit, Ministry of Public Service, Energy and Public Utilities. 2018. Belize - Annual Energy Statistics Report.
- Electricity Law №13, 1992 (Belize).

Bolivia

- National Cargo Dispatch Committee (CNDC), Ministry of Hydrocarbons and Energies. 2022. Annual Report 2021 - Operation Results.
- CNDC. Visited September 30, 2022. Setting up of the Wholesale Electricity Market. Available at: https://www.cndc.bo/empresa/conformacion.php
- Rural Electrification Cooperative. June 2019. Smart Single-Phase Meter - Technical Specification NTCRE 008/19-SAP 5346. Available at: https://www.cre.com.bo/wp-content/uploads/2019/07/19-MEDIDOR-MONOFASICO-CL-1-5-80-A-50-Hz-INTELIGENTE-6-2019.pdf
- Law 1604, December 21, 1994. Bolivian Electricity Law.

Brazil

- Brazilian Association of Electric Energy Distributors (ABRADEE). Visited September 30, 2022. Website. "SECTOR OVERVIEW". Available at: https://www.abradee.org.br/setor-eletrico/visao-geral-do-setor/
- IDB. April, 2022. Energy dossier 2022, Brazil: focus on the electricity sector.
- National Bank for Economic and Social Development (BNDES). December 2013. Smart grid: opportunity for local productive and technological densification.

- Bnamericas. July 2020. News: "Under the spy glass: smart meters in Latin America". Available at: https://www.bnamericas.com/es/reportajes/bajo-la-lupa-los-medidores-inteligentes-en-america-latina
- Chamber of Electricity Trade, Brazil (CCEE). January 2022. News: "Open energy market breaks record for migration of consumer units in 2021". Available at: https://www.ccee.org.br/pt/web/guest/-/mercado-livre-de-energia-bate-recorde-de-migracao-de-unidades-consumidoras-em-2021
- Energy Research Company (EPE). June 2022. Statistical Yearbook of Electric Energy 2022.
- Enel Distribution RIO. Visited September 30, 2022. Low Voltage Tariffs. Available at: https://www.enel.com.br/content/dam/enel-br/one-hub-brasil---2018/tarifas-taxas-impostos/rio/Tarifa%20enel%20Rio_Julho%202022.pdf
- Law Nº 9.427, December 26, 1996 (Brazil)
- Ministry of Mines and Energy (MME). Visited September 30, 2022. Research and Development and Energy Efficiency. Available at: https://www.gov.br/aneel/pt-br/centrais-de-conteudos/manuais-modelos-e-instrucoes/pesquisa-e-desenvolvimento-e-eficiencia-energetica
- MME. June 2022. News: "Analysis for the standardization of distributed energy resources released by ANEEL". Available at: https://www.gov.br/aneel/pt-br/assuntos/noticias/2022/analise-para-normatizacao-de-recursos-energeticos-distribuidos-e-divulgada-pela-aneel
- MME. Energy Research Company (EPE). 2020. National Energy Plan - PNE2050.
- MME. 2010. Smart Grids. Smart Grids Working Group.
- MME. June 2022. Visited September 30, 2022. News "Analysis for standardization of distributed energy resources released by ANEEL". Available at: https://www.gov.br/aneel/pt-br/assuntos/noticias/2022/analise-para-normatizacao-de-recursos-energeticos-distribuidos-e-divulgada-pela-aneel
- Neoenergía (Iberdrola). June 2020. News pilot project "Neoenergy brings smart meters to the interior of São Paulo". Available at: https://www.neoenergia.com/es-es/sala-de-comunicacion/noticias/Paginas/neoenergia-lleva-medidores-inteligentes-interior-de-sao-paulo.aspx
- Brazilian Standard: ABNT NBR 16968 - DLMS/COSEM Profile for Smart Electric Energy Meters - Requirements (Brazil).

Chile

- Library of the National Congress of Chile (Nicolás García Bernal). March 2019. Installation of smart meters.

- BNamericas. Visited September 30, 2022. News: "Under the spy glass: smart meters in Latin America". Available at: https://www.bnamericas.com/es/reportajes/bajo-la-lupa-los-medidores-inteligentes-en-america-latina
- National Energy Commission (CNE - Chile). 2021. Energy Statistical Yearbook.
- CNE - Chile. August 2019. Technical Annex - Measurement, Monitoring and Control Systems.
- CNE - Chile. December 2019. Technical Service Quality Standard for Distribution Systems.
- CNE - Chile. Visited September 30, 2022. Pricing. Available at: CNE - Chile https://www.cne.cl/tarificacion/electrica/valor-agregado-de-distribucion/
- CNE - Chile. Visited September 30, 2022. Pricing 2020-2024. Available at: https://www.cne.cl/tarificacion/electrica/valor-agregado-de-distribucion/vad-2020-2024-y-servicios-asociados/
- CNE – Chile. Visited September 30, 2022. Pricing 2024-2028. Available at: https://www.cne.cl/en/tarificacion/electrica/
- General Industrial Electricity Company. Visited September 30, 2022. Regulatory Entities of the Electricity Sector. Available at: https://www.cge.cl/sector-electrico/entidades-reguladoras-del-sector-electrico/
- National Electrical Coordinator of Chile. Visited September 30, 2022. Website of the Directory of Coordinated Companies. Available at: https://www.coordinador.cl/directorio-de-empresas-coordinadas/
- Decree 327 of the Ministry of Mining (Chile). Regulations of the General law of Electricity Services. Ministry of Mining.
- Enel. Visited September 30, 2022. Tariff concepts. Available at: https://www.enel.cl/es/clientes/tarifas-y-regulacion/conceptos-tarifas.html
- Enel. Visited September 30, 2022. Smart metering. Available at: https://www.enel.cl/es/clientes/informacion-util/medicion-inteligente.html
- Law 21076 of the Ministry of Energy (Chile) amending the General Law of Electricity Services is to impose on the energy distribution company the obligation to pay for the removal and replacement of the connection and meter in the event of unusable facilities by force majeure.
- Ministry of Energy. October, 2013. Smart Grids: Development Opportunities and Implementation Strategy in Chile.
- Project amending Law No. 21.076 to make voluntary for users the change of meters or connections by the concessionaire of the public distribution service (Bulletin No. 12450-08, Chamber of Deputies of Chile).

Colombia

- IDB, Ministry of Mines and Energy, Ministry of Information Technology and Communications, Mining-Energy Planning Unit, Intelligent Colombia Initiative. April 2020. Smart Grids: Colombia Vision 2030. Part III Policy and Regulation.
- Energy and Gas Regulation Commission (CREG). December 2020. Inputs for the Analysis of Net Benefits of Alternatives for the Implementation of the Advanced Metering Infrastructure in the Non-Productive Sector.
- Econometrics Consultants. December 2020. Results: "Analysis of Net Benefits of Advanced Metering Infrastructure Alternatives in the National Interconnected System". Available at: https://www.creg.gov.co/sites/default/files/presentacion_ami_29-12-2020_v2.pdf
- Public Companies of Medellín E.S.P.. February 2022. Rates and Cost of Electric Power - Regulated Market.
- Public Companies of Medellín E.S.P. Visited September 30, 2022. Prepaid Energy. Available at: https://cu.epm.com.co/clientesyusuarios/energia/hogar/energia-prepago.
- Interconexión Eléctrica S.A. E.S.P. ISA. Visited September 30, 2022. Certification of outstanding shareholders. Available at: https://www.isa.co/es/grupo-isa/composicion-accionaria/
- Latin American Organization of Energy, Foreign Relations - Trade and Development of Canada. March 2013. Market Models, Economic Regulation and Tariffs of the Electricity Sector in Latin America and the Caribbean (Colombia).
- Draft Resolution 701-011 of 2022, of the CREG (Colombia), amending Titles II, V, VI and VII of CREG Resolution 101 001 of 2022.
- Resolution 097 of 2008, of the CREG (Colombia), approving the general principles and methodology to fix charges for the use of the Regional Transmission and Local Distribution Systems.
- Resolution 101-001, of the CREG (Colombia), establishing the conditions for the implementation of the advanced measurement infrastructure in SIN.
- Resolution 40072 of 2018, of the Ministry of Energy and Mines (MEM - Colombia), creating the mechanisms to implement the advanced metering infrastructure for the public electric power service.
- Resolution 40459 of 2019, MEM - Colombia, amending Resolution 40072 of 2018.
- Resolution 40483 of 2019, MEM - Colombia, amending Resolution 40072 of 2018.
- CREG Resolution 128/1996, of the CREG, setting forth rules on participation in electricity generation, distribution and commercialization activities and shareholding limits between companies with complementary activities, prohibiting any generation company from holding than 25% participation in commercialization.

- Resolution No. 30 of 2018, of the CREG, which regulates small-scale self-generation activities and distributed generation in the National Interconnected System (SIN).
- Resolution No. 38 of 2010, of the CREG, amending CREG Resolution 199 of 1997.
- Ruling C-186/22 of the Constitutional Court (Colombia) declaring unenforceable subparagraph 2 of article 56 of Law 2099 of 2021, thus allowing the cost of the smart meter and its installation to be transferred to the user.
- Delegate Superintendency for Energy and Fuel Gas, Technical Department of Energy Management. June 2022. Diagnosis on the Status of Electricity Measurement in SIN (January to December 2021).
- Delegate Superintendence for Energy and Fuel Gas, Energy and Natural Gas Market Monitoring Unit. August 2022. Market Follow-up and Monitoring Newsletter.
- Mining-Energy Planning Unit (UPME). December 2020. Final Project Report. Support for the deployment of smart grid technologies in Colombia.
- XM Electricity market administrators (XM). January 2022. Energy demand in 2021 marks all-time highs.
- XM. Visited September 30, 2022. List of National Transmission Operators. Available at: https://www.xm.com.co/sites/default/files/documents/AgentesRegistrados_1.xlsx
- XM. Visited September 30, 2022. Users in the Unregulated Electricity Market as of June 2022. Available at: https://sinergox.xm.com.co/infms/_layouts/15/WopiFrame.aspx?sourcedoc={BA20F570-CE49-431B-993E-9FE69341B597}&file=UNR_2do_Trimestre2022.xlsx&action=default
- XM. Visited September 30, 2022. Number of distributors registered with XM as of August 2022. Available at: https://www.xm.com.co/sites/default/files/documents/AgentesRegistrados_1.xlsx

Costa Rica

- Statistical Yearbook 2019-2020, Compendium of National Statistics of the National Institute of Statistics and Censuses of Costa Rica (INEC). 2020. National Institute of Statistics and Censuses of Costa Rica.
- Public Services Regulatory Authority. RE-0037-IE-2022, June 22, 2022.
- Central American Bank for Economic Integration. January 2018. Comparative analysis of the regulatory framework, incentives and existing price tariff system, for the purchase/generation of electricity from renewable energy plants in Central America and Panama (Costa Rica).
- IDB. 2013. Energy Dossier (Costa Rica).

- BNamericas. Visited September 30, 2022. Grupo ICE will install over 600,000 smart meters by the end of 2022. Available at: https://www.bnamericas.com/es/noticias/grupo-ice-superara-600000-medidores-inteligentes-instalados-al-finalizar-2022
- Compañía Nacional de Fuerza y Luz, S.A. 2019. Project for the installation of smart meters in the Escazú Branch service area. Available at: https://www.cnfl.go.cr/contenido/documentos/transparencia/proyectos/proyecto-medidores-inteligentes.pdf
- Decree No. 39220 of the Ministry of the Environment and Energy setting forth the regulations for distributed generation for self-consumption with renewable sources; simple grid metering contracting model.
- Government of Costa Rica. February, 2019. National Decarbonization Plan 2018-2050, Government of Costa Rica.
- Costa Rican Institute of Electricity. January 2018. Construction Standards Manual, Volume I, Standardized Materials and Equipment.
- Law No. 8345, Law for the Participation of Rural Electrification Cooperatives and Municipal Public Service Companies in National Development.
- Economic and Commercial Office of the Spanish Embassy in Panama. November 2021. The Electricity Sector in Costa Rica.
- Secretariat of Planning of the Energy Subsector (SEPSE) and Ministry of Environment and Energy (MINAE) - Costa Rica. February 2021. National Smart Grid Strategy 2021-2031.

Dominican Republic

- Economic Commission for Latin America and the Caribbean. 2020. Energy transition in the Dominican Republic. How do the decarbonization strategies of the electricity sector accelerate the participation of the private sector in the Nationally Determined Contribution?
- Edeeste. Visited September 30, 2022. Change of ownership in contract. Available at: https://edeeste.com.do/inicio/servicios/cambio-de-titularidad/
- Edeeste. Visited September 30, 2022. Virtual office. Available at: https://oficinavirtual.edeeste.com.do/
- Edeeste. Visited September 30, 2022. Prepaid energy system. Available at: https://edeeste.com.do/inicio/aprende-con-edeeste/sistema-energia-prepago/
- Edenorte. Visited September 30, 2022. Change of ownership in contract. Available at: https://edenorte.com.do/servicios/cambios-titular-contrato/
- Edenorte. Visited September 30, 2022. Information on electricity rates. Available at: https://edenorte.com.do/tarifas/
- Edesur. Visited September 30, 2022. Change of ownership in contract. Available at:

https://www.edesur.com.do/media/r5gbdibp/cambio-de-titular

- Edesur. Visited September 30, 2022. Contracting the service. Available at: https://www.edesur.com.do/media/biqp1sws/contratacion-de-servicio
- General Electricity Law No. 125-01 and Application Regulations (Dominican Republic).
- Law No. 186-07 amending the General Electricity Law No. 125.01, dated June 26, 2001. (Dominican Republic).
- Law No. 57-07 (Dominican Republic).
- Energy Monitor, Ministry of Economy, Planning and Development. April 2022. Losses of energy distribution companies.
- National Statistics Office (ONE). Visited September 30, 2022. Number of customers per year, companies and type of user by electricity distributor 2004-2020. Available at: https://web.one.gob.do/datos-y-estadisticas/temas/estadisticas-economicas/estadisticas-sectoriales/energia/
- ONE. Visited September 30, 2022. Energy billed per year, by distribution company and type of user 2004-2020. Available at: https://web.one.gob.do/datos-y-estadisticas/temas/estadisticas-economicas/estadisticas-sectoriales/energia/
- Latin American Energy Organization (OLADE). August 2017. News: "OLADE completes a study of distributed generation and energy measuring in the Dominican Republic". Available at: https://www.olade.org/noticias/olade-finaliza-estudio-de-generacion-distribuida-y-medicion-de-energia-en-republica-dominicana/
- OLADE. January 2013. Regulatory and Tariff Elements – Dominican Republic Case. Available at: https://edenorte.com.do/tarifas/
- Resolution SIE-52-2005 on electricity (Dominican Republic).
- Resolution SIE-52-2005, of the Superintendence of Electricity (Dominican Republic).
- Superintendence of Electricity. 2020. Annual Report. 2019.
- Superintendence of Electricity. January 2020. Estimation of the implicit subsidy in the tariff granted to the regulated users of the Public Electricity Service offered by distribution companies: Edesur, Edeeste and Edenorte.

Ecuador

- Agency for the Regulation and Control of Energy and Non-Renewable Natural Resources of Ecuador. 2021. Annual and multi-annual statistics of the Ecuadorian electricity sector for the year 2020.
- National Assembly. January 2015. Organic Law of the Public Electric Power Service.
- National Center for Energy Control of Ecuador (CENACE). 2020. Annual Report 2019.

- Empresa Eléctrica Quito S.A. E.E.Q. September, 2022 Official Public Procurement System - "Acquisition and implementation of an Advanced Measurement System (AMI) for the service area of Empresa Eléctrica Ambato Regional Centro Norte S.A. (EEASA), Empresa Eléctrica Provincial Cotopaxi S.A. (ELEPCOSA), Empresa Eléctrica Regional Norte S.A. (EMELNORTE), Empresa Eléctrica Quito S.A. (EEQ) and Empresa Eléctrica Regional Centro Sur C.A. (CENTROSUR)". Available at: https://www.compraspublicas.gob.ec/ProcesoContratacion/compras/PC/informacionProcesoContratacion2.cpe?idSoliCompra=KPWKJi3pW-jvzUM8m1STscP4TifixeTP-bAwW3PQk3N4
- Ministry of Electricity and Renewable Energy (MERNNR) in collaboration with the Inter-American Development Bank, 2017. National Energy Efficiency Plan (2016 - 2035).
- MERNNR. January 2019. Invitation to submit an expression of interest for the "Implementation of the Advanced Metering System for Electricity Companies (Centrosur, Ambato, Emelnorte, Elepcosa and Quito)".

El Salvador

- AES El Salvador. Visited September 30, 2022. Mobile website for customers. Available at: https://www.movilaesweb.com/#/
- AES El Salvador. Visited September 30, 2022. Example of tariff schedule. Available at: https://www.aes-elsalvador.com/sites/default/files/2022-04/1.CAESS%20Tarifa%203x6%2C5%2014%20de%20Abril%202022-01.jpg
- AES El Salvador. July, 2021. Press release. "AES will install the first 100% smart network." Available at: https://www.aes-elsalvador.com/es/aes-instala-primera-red-100-inteligente
- BID. 2013. Energy Dossier (El Salvador).
- BNamericas. Visited September 30, 2022. AES promotes the digitization of electricity distribution services in El Salvador. Available at: https://www.bnamericas.com/es/noticias/aes-impulsa-la-digitalizacion-de-los-servicios-de-distribucion-electrica-en-el-salvador
- Economic Commission for Latin America (ECLAC). 2021. Synthesis of Key Definitions for the Energy Transition in El Salvador.
- National Energy Council (CNE – El Salvador). 2015. Report on the electricity sector in El Salvador.
- CNE – El Salvador. 2020. El Salvador Energy Policy 2020-2050.
- Decree No. 70 Regulation of the General Electricity Law.
- Decree No. 84 of the Legislative Assembly (Republic of El Salvador). General Electricity Law.
- General Superintendence of Electricity and Telecommunications (SIGET). April 2021. Electricity Market of El Salvador.
- SIGET. 2020. Electrical Statistics Bulletin Nº 22.

Guatemala

- IDB. 2013. Energy Dossier (Guatemala).
- National Electric Power Commission (CNEE - Guatemala). 2022. Electricity distributors in Guatemala.
- CNEE - Guatemala. June 2005. Legal Framework of the Electricity Subsector of Guatemala, Compendium of Laws and Regulations.
- EEGSA (EMP Group). May 2020. Guide to use the Hourly Rate and Smart Consumption Portal.
- EEGSA. Visited September 30, 2022. Tariff information. Available at: https://eegsa.com/factura-eegsa-2/calculadora-de-facturas/informacion-de-tarifas/
- EEGSA. March 2021. Management Report 2021.
- Ministry of Energy and Mines (MEM-Guatemala). January 2019. Statistics of the electricity subsector in 2017.
- MEM-Guatemala. January 2022. Transportation System Expansion Plan (2022 - 2052).
- MEM-Guatemala. September 2019. Electricity Coverage Index - 2017.

Guyana

- Government of Guyana. September 1999. Electricity Sector Reform Act, 1999.
- Guyana Energy Agency. Visited September 30, 2022. Draft Strategic Plan (2016 - 2020): Reliable economically, environmentally and socially sustainable energy for all in Guyana. Available at: https://gea.gov.gy/downloads/Strategic-Plan-2016-2020.pdf
- Guyana Power & Light (GPL). Visited September 30, 2022. Web Portal - Guyana Power and Light (GPL). Available at: https://gplinc.com/about-us/who-we-are/
- Our World in Data. 2022. Visited September 30, 2022. Guyana: Energy Country Profile. Available at: https://ourworldindata.org/energy/country/guyana#how-much-electricity-does-the-country-consume-each-year

Haiti

- Electricité d'Haiti (EDH). Visited September 30, 2022. History of Electricity in Haiti. Available at: https://edh.ht/notre-histoire.php
- International Energy Agency. Visited September 30, 2022. Data and statistics website. Available at: https://www.iea.org/data-and-statistics/data-browser?country=HAITI&fuel=Energy%20consumption&indicator=TotElecCons

Honduras

- IDB. 2013. Energy Dossier (Honduras).
- Electric Power Regulatory Commission (CREE). Visited September 30, 2022. Tariff structure to be applied by the ENEE for billing as of July 2022. Available at: https://www.cree.gob.hn/tarifas-vigentes-enee/
- Decree No. 158-94. 1994. Framework Law of the Electricity Subsector (Honduras).
- El Heraldo. May, 2017. Visited September 30, 2022. Empresa Energía Honduras Company will install 500,000 smart power meters. Available at: https://www.elheraldo.hn/economia/honduras-la-empresa-energia-honduras-instalara-500000-medidores-de-luz-inteligentes-FBEH1072070
- Empresa Energía Honduras (EEH). Visited September 30, 2022. Technical specifications for AMI centralized measuring. Available at: https://docplayer.es/83222666-Especificaciones-tecnicas-medicion-tipo-ami-centralizada.html
- National Electric Power Company (ENEE - Honduras). December 2021. Statistical Newsletter - December 2021.
- ENEE - Honduras. November 2012. Service Information: Service interruptions.
- ENEE - Honduras. November 2012. Services Information: New electricity installations.
- Superintendency of Public-Private Partnerships. 2017. Public-Private Partnership contract for the recovery of losses in services provided by the National Electric Power Company (ENEE) for the execution of "Distribution and Financial flows".

Jamaica

- International Energy Agency. Data and statistics website. Visited September 30, 2022. Available at: https://www.iea.org/data-and-statistics/data-browser?country=JAMAICA&fuel=Energy%20consumption&indicator=TotElecCons
- Jamaica Public Service Company (JPS). August 2011. Articles of Incorporation. Available at: https://www.jpsco.com/about-jps/
- JPS. Visited September 30, 2022. Shareholder website. Available at: https://www.jpsco.com/about-jps/
- JPS and Government of Jamaica. Notifice published in the Official Gazette of Jamaica. August 2022. Initiative to create a smart electricity grid.
- JPS. Annual Reports. 2016, 2017, 2018, 2019
- JPS. Tariff Adjustment Report.

- JPS. Visited September 30, 2022. Website: "Let's take the journey towards a smarter grid together". Available at: https://www.jpsco.com/smart-meter-brochure/
- JPS. Date not available. Business Plan for 2019-2024.
- Jamaica Office of Public Utilities Regulation. Visited September 30, 2022. Tariff Proposal website . Available at: https://our.org.jm/document/jps-tariff-2019-2024-application-5/
- Jamaica Office of Regulation of Public Services. Visited September 30, 2022. Web portal on tariff adjustment. Available at: https://our.org.jm/wp-content/uploads/2022/05/JPS-Annual-Filing-2022-FINAL_May-10-2022.pdf

Mexico

- Federal Electricity Commission of Mexico (CFE). April 2015. Advanced metering infrastructure systems (AMI).
- CFE. Januar, 2015. Interactive System and Advanced Infrastructure for measuring electrical energy.
- CFE. February 2019. Program for the Expansion and Modernization of the General Distribution Networks 2019-2033.
- Energy Regulatory Commission (CRE – México). September 2014. Smart Grid Regulatory Framework (REI) in Mexico.
- CRE - México and Ibero-American Association of Energy Regulatory Entities (ARIAE). May 2004. Tariff Structure of the Mexican Electricity Sector.
- Government of Mexico. Visited September 30, 2022. Energy consumption website. Available at: http://dgeiawf.semarnat.gob.mx:8080/ibi_apps/WFServlet?IBIF_ex=D2_ENERGIA06_20&IBIC_user=dgeia_mce&IBIC_pass=dgeia_mce&NOMBREENTIDAD=*&NOMBREANIO=*
- Mexican Energy Transition Law. New law published in the Official Gazette of the Federation on December 24, 2015.
- Law of the Public Electric Energy Service of Mexico. Last reform published, DOF 28-05-2021.
- Secretariat of Energy of Mexico (SENER). 2017. Smart Grid Program.
- SENER. 2013. National Energy Strategy 2013-2027.
- SENER. 2017. Smart Grid Program.

Nicaragua

- Economic Commission for Latin America (ECLAC). August 2015. National Report on Monitoring Energy Efficiency in Nicaragua.
- DISNORTE, DISSUR. Visited September 30, 2022. Virtual consumer office. Available at: https://www1.disnorte-dissur.com.ni/
- Nicaraguan Energy Institute. 2021. Summary of the main indicators of the electricity subsector.
- Law No. 272, Electricity Industry Law.
- Ministry of Energy and Mines (Nicaragua). Visited September 30, 2022. Electricity Market - Licenses and Concessions. Available at: https://www.mem.gob.ni/?page_id=1460

Panama

- Agreement No. 013-2021 of the Administrative Court of Public Procurement, of September 15, 2021, which adopts the procedure for processing electronic evidence and procedural management, based on digital information and communication technologies, which allow the Administrative Court of Public Procurement (the Court), to receive, execute and manage regular proceedings to safely and effectively, guarantee compliance with its legal and regulatory powers.
- National Assembly, General Secretariat. July 2021. Draft Law 041, issuing provisions related to the provision of public electricity service.
- National Authority for Public Services of Panama. 2022. Electricity rates for regulated customers in effect from July 1 to December 31, 2022.
- National Authority for Public Services. 2022. Procedure to enforce article 15 of Law 295 of April 25, 2022 (Electric mobility).
- National Authority for Public Services (ASEP). August 2016. Procedure for self-consumption of new, renewable and clean sources.
- ASEP. August 2019. Regulation of Distribution and Commercialization of Electric Power-Title X: Standards of quality of the commercial service.
- ASEP. December 2021. Statistics. Panamanian electricity market.
- ASEP. January 2018. Rules for the wholesale electricity market.
- ASEP. July 2022. Wholesale market indicators.
- ASEP. March 2013. Distribution and Marketing Regulations - Title XI: Measuring standards applicable to regulated customers.
- ASEP. May, 2010. Criteria and procedures for the sale of energy and power to large customers.

- BID. 2013. Energy Dossier (Panama).
- National Dispatch Center (ETESA). September 2019. Methodology to manage the rationing of electricity supply.
- Metro-Oeste Electrical Distribution Company, S.A. December 2021. Financial statements.
- ENSA. 2022. Tariff in effect from January 1 to June 30, 2022.
- ENSA. Visited September 30, 2022. Query: "Can I change my bill?". Available at: https://www.ensa.com.pa/preguntas-frecuentes/facturacion/puedo-cambiar-de-tarifa#:~:text=El%20cliente%20podr%C3%A1%20cambiar%20la,los%20requisitos%20para%20cada%20tarifa
- National Government of Panama. Agreement No. 013-2021, Wednesday, September 15, 2021, which adopts the procedure for processing evidence and managing electronic processes, based on digital information technologies.
- Law No. 6 of February 3, 1997. Regulatory and institutional framework for the public electricity service.
- Law No. 81 of March 26, 2019. Protection of Personal Data.
- Ministry of Economy and Finance of the Republic of Panama. December 2017. Analysis of the Panamanian Electricity Market.
- Ministry of the Presidency, Secretariat of Energy (SEN). September 2021. National Distributed Generation Strategy.
- Ministry of the Presidency, SEN. 2020. Visited September 30, 2022. Electric Energy Balance. Available at: https://www.energia.gob.pa/archivos/#

Paraguay

- National Electricity Administration (ANDE). 2020. Annual Report 2019.
- ANDE. August, 2020. Press release: "Implementation of a Remote Data Collection and Management System Using Smart Meters". Available at: https://www.ande.gov.py/interna.php?id=7520#.ZAjjjj3MKMp
- Development Bank of Latin America (CAF). November 2021. Available at: https://www.caf.com/es/actualidad/noticias/2021/11/ande-suscribe-un-convenio-con-caf-para-la-implementacion-de-un-sistema-inteligente-de-medicion-de-energia-electrica-en-el-paraguay/
- Law No. 966 of 2014 creating the National Electricity Administration (ANDE) as an autonomous entity and setting forth its organic charter. A state owned company ANDE operates under a monopoly regime for the transmission, distribution and commercialization of energy in Paraguay.

- Itaipu Technological Park. March 2022. News: "Itaipu and ANDE conclude conversations on the implementation of the SAMR. Available at: https://www.pti.org.py/pti-y-ande-finalizaron-conversaciones-sobre-implementacion-del-samr/

Peru

- Decree Law No. 25844, Electricity Concessions Law (OSINERGMIN).
- Supreme Decree (Nº 018-2016-EM) that modifies the Regulation of the Law of Electric Concessions, Transmission Regulation, and the Regulation of Unregulated Electricity Users.
- Supreme Decree DS-018-2016 that modifies the Regulation of the Electricity Concessions Law, Transmission Regulation and the Regulation of Unregulated Electricity Users.
- Electro Ucayali. May, 2019. Study of technological innovation and/or energy efficiency projects.
- Tariff Regulation for the Management of Electricity Distribution. July 2019. Distribution Value Added (VAD) 2019-2023.
- Tariff Regulation for the Management of Electricity Distribution. October 2019. Distribution Value Added (VAD) 2019-2023.
- Ministry of Energy and Mines (MEM - Perú). 2018. Proposal for a Regulatory Framework for the development of Smart Grids and Distributed Generation in Peru.
- MEM - Peru. January 2022. Chapter 4 - Electrical power distribution. Available at: https://www.minem.gob.pe/minem/archivos/Capitulo%204%20Transmision%20electrica%202020.pdf
- MEM - Peru. January 2022. Chapter 5 - Electrical power distribution. Available at: https://www.minem.gob.pe/minem/archivos/Capitulo%205%20Distribucion%20de%20energia%20electrica%202020.pdf
- Supervisory Agency for Investment in Energy and Mining (OSINGERGMIN). 2019. Analysis of the proposals for Smart Measurement Systems (SMI).
- OSINGERGMIN. 2022. Approved End User Tariffs.
- Resolution of the Board of Directors OSINGERGMIN (Peru) No. 225-2017-OS/CD.
- Resolution of the Board of Directors OSINGERGMIN (Peru) No. 078-2006-OS/CD approving the special procedure, criteria and calculation procedures for setting prepaid service rates.
- Sociedad Eléctrica del Sur Oeste S.A. June, 2019. Replacement plan for smart metering systems.

Suriname

- International Energy Agency. Visited September 30, 2022. Data and statistics website. Available at: https://www.iea.org/data-and-statistics/data-browser?country=SURINAME&fuel=Energy%20consumption&indicator=TotElecCons
- IDB. September, 2019. Environmental and Social Impact Assessment for Energy Infrastructure Projects.
- Electricity Law No. 42 of March 16, 2016 (Suriname).

Trinidad and Tobago

- International Energy Agency. Visited September 30, 2022. Data and statistics Portal. Available at: https://www.iea.org/data-and-statistics/data-browser?country=TRINIDAD&fuel=Energy%20consumption&indicator=TotElecCons
- IDB. February 2016. Energy Dossier: Trinidad & Tobago.
- Electricity Commission of Trinidad and Tobago. 2015. AMI Project.
- Electricity Commission of Trinidad and Tobago. March 2017. Smart Grid - Advanced Metering Infrastructure.
- Government of Trinidad and Tobago and Inter-American Development Bank. 2015. A Unique Approach for Sustainable Energy in Trinidad and Tobago.
- Government of Trinidad and Tobago. 2013. Facing the issues: Turning the economy around.

Uruguay

- National Administration of Electric Power Plants and Transmission (UTE). Visited September 30, 2022. Energy sales information. Available at:

  https://portal.ute.com.uy/institucional/ute/utei/informacion-de-venta-de-energia
- UTE. Date not available. Strategic plan. 2020-2021.
- UTE. 2021. Conditions and Specifications for the Supply to the UTE of direct electronic three-phase meters of active and reactive energy for double and triple tariff for customers.
- UTE. Visited September 30, 2022. Household electricity tariffs. Available at: https://www.ute.com.uy/clientes/soluciones-para-el-hogar/planes-hogar/plan-inteligente#tab-323-10
- UTE. 2020. United Nations Global Compact. Communication of Progress 2020.

- UTE. Visited September 30, 2022. Digital Diary. Available at: https://www.ute.com.uy/noticias/ute-y-la-agenda-digital-50-de-medidores-inteligen-tes-en-2020
- IDB. January, 2017. Energy Dossier: Uruguay.
- Faculty of Engineering. Institute of Computing (Uruguay). May 2018. Risks and opportunities for the electricity market because of changes in the energy matrix.
- Law No. 16832, Energy Market Regulatory Law (Uruguay). 1997.

Venezuela

- International Energy Agency. Visited September 30, 2022. Data and Statistics Portal. Available at: https://www.iea.org/data-and-statistics/data-browser?country=VENEZU-ELA&fuel=Energy%20consumption&indicator=TotElecCons
- Organic Law of the Electricity System - Service Number 39573. December 2010.

Other bibliography and reference regulation

- IDB. March 2022. Empowering Electricity Consumers Through Demand Response: Why and How.
- French Energy Regulatory Commission. 2022. CRE defines the new regulatory framework for the Linky project. Energy Regulatory Commission. In: The CRE defines the new regulatory framework for the Linky project – CRE.
- Decree No. 2010-1022 of August 31, 2010 regarding metering devices in public electricity networks (France).
- Deliberation of the Energy Regulation Commission No. 2022-64 of February 24, 2022 on the draft decision on the incentive regulatory framework for the Enedis smart meter system in the BT voltage range ≤ 36 kVA (Linky) for 2022-2024 and amendment to Resolution No. 2021-13. France.
- Deloitte. 2020. The future of regulation.
- Directive 2009/28/CE of the European Parliament and of the Council, of April 23, 2009, regarding the promotion of the use of energy from renewable sources and amending and repealing Directives 2001/77/CE and 2003/30/CE.
- European Commission, Directorate-General for Energy, Alaton, C., Tounquet, F. 2020. Benchmarking smart metering deployment in the EU-28: final report, Publications Office. Available at:
  https://data.europa.eu/doi/10.2833/492070
- Giordano, Vincenzo et al. 2012. Guidelines for cost benefit analysis of smart metering deployment - Publications Office of the EU. European Union. Available at: https://op.europa.eu/en/publication-detail
- International Energy Agency. 2019. Available at: https://www.iea.org
- Smarter Together. 2019. Report on deployment of Linky smart power meters in the area - D3.4.2 – Version 2.0.
- 2012/148/UE: Commission Recommendation, of March 9, 2012, regarding preparations for the deployment of smart meter systems (OJ L 73 13.03.2012, p. 9, ELI. Available at: http://data.europa.eu/eli/reco/2012/148/oj

BID