Electrokit: Power Utility Toolkit–Electricity Loss Reduction

Energy Division

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Acronyms

AMI	Automated Metering Infrastructure
BI	Business Intelligence
CEER	Council of European Energy Regulators
CMS	Customer Management System
DG	Distributed Generation
ED	External Dispersion
GIS	Geographic Information System
IDB	Inter-American Development Bank
ISO	International Organization for Standardization
Kwh	Kilowatt hour
LAC	Latin America and Caribbean
NGO	Non-Government Organization
NPV	Net Present Value
NIS	Network Information System
OECD	Organization for Economic Co-Operation and Development
OLADE	Latin America Energy Organization
O&M	Operations and Maintenance
SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goals
SOE	State-Owned Enterprises
TWh	TeraWatt hours

1. Introduction

Companies providing electricity services face the need to continuously improve the quality of its services to society, ensure and broaden its coverage, maximize the impact of its investments, and operate in an efficient manner. Distribution companies have also the need to adapt to the new demands from consumers, who are gradually having a more active role. These are some of the main characteristics of the license to operate utilities have in their geographic coverage. In addition, state-owned enterprises (SOE) in the electricity sector have the added challenges of: (i) serving policy objectives which are specific to each country and in some cases, (ii) having limited capacity to invest considering their financial constraints.

To achieve these multiple - and sometimes conflicting objectives - utility companies must have robust business models to provide services with quality; and internal learning schemes to strengthen their technical and human capabilities to improve their operational performance. In addition, utilities must have planning and management models aimed at developing and implementing successful transformation processes, assuring the viability of its investments and services.

The Electrokit: Power Utilities Toolkit was developed to support electricity companies in the Latin America and Caribbean region (LAC) identify opportunities to improve their performance, considering the important participation of SOEs in the LAC region[1]. This development takes into consideration the extensive experience of the Bank working with utilities in multiple countries[2] and international standards in the industry such as International Organization for Standardization (ISO).

The methodology integrally evaluates the utilities, from the quantitative aspects of their performance to the qualitative elements of their processes, practices and technologies used in the management cycle. On the quantitative aspects, the toolkit brings several performance indicators for each activity which can be used as a reference to assess the utility's performance. The toolkit is universally applicable to any type and size of company worldwide, including SOEs. The document also acknowledges the different levels of maturity and sophistication of electricity utilities in the LAC region, and it has been developed to provide this guidance to utilities improve their performance.

The Electrokit however is not a certification tool or an audit instrument; it is a practical managerial and technical guide to identify improvement opportunities in priority activities, which will be specific to each utility and country setting. Moreover, the best practices do not detail the extent of applicability to a certain enterprise according to its level of maturity, scale,

[1] Government-owned utilities represent the single largest distribution companies, representing 39% of the distribution companies in the LAC region. Source: Fitch ratings https://your.fitch.group/rs/732-CKH-767/images/Fitch_10086090.pdf?mkt_tok=eyJpIjoiTXpsaFl6QTBNMlExWlRJMCIsInQiOiJwVHBVZjVncDZoT29zcFZTM0JadVlcL1VjaWN1dDM2bnJHR3phU1lJSkpkVU5qNlE5OXB6MXgxSmE4ejRzcjJIVHhIZWJEaXZBYm92amtFYW81UUZObmc9PSJ9

[2] For example, the Bank has developed the Aquarating toolkit (https://aquarating.org/en/) to improve the performance of water and sanitation companies, and the lessons learned from this development were included in this document.

regulatory framework and market context as these will be tailored to each case. These improvement opportunities are usually developed in a program of activities with targets and the IDB can make available to utilities a team to help elaboration of these activities and monitor them over time.

1.1 Defining the Electrokit

What is it?

The Electrokit is an initiative created by the Inter-American Development Bank (IDB) to strengthen transformation and continuous improvement of electric utilities. The toolkit follows international standards that characterize and evaluate utilities based on indicators and best practices. These practices are grouped in 4 areas and 16 activities that are common to most electricity utility.

The aim of the Electrokit is to provide LAC power utilities, policy and decision-makers access to best practices, current trends and expertise to: (i) identify challenges, develop a strategy and action plan for addressing them; and (ii) support utilities to be more sustainable, efficient, improve customer experience and accelerate innovation to allow the utilities to stay ahead of the rapidly sector transformation.

Companies providing electricity distribution services face the daily challenge of continuously improving services, and in this scenario, companies must seek management models aimed at continuous learning and implementing performance improvement processes. One way to achieve these objectives is to always seek the best practices in the sector.

In general, the challenges for public electricity distribution companies are to ensure:

(i) the continuity and reliability of electricity service.
(ii) the affordability of the service.
(iii) the efficiency in the provision of service.
(iv) the required transformation to embrace existing and new demands such as distributed generation and electromobility; and
(v) the sustainability of the utility and the sector.

In addition to these, SOEs have the additional challenges due to their mix of social, economic, political, and strategic interests.

These challenges when properly managed, can be transformed into opportunities for the LAC region, such as: (i) positive impacts on the competitiveness of countries from the improvement of the quality and reliability of services ; (ii) reduce inequality by improving the affordability of service, in particular to the most vulnerable populations; (iii) better use of society’s limited resources by strengthening the efficiency in provision of service and the financial sustainability of the companies through the reduction of electricity losses; (iv) anticipate new trends to ensure they are better prepared for disruptions in the sector, incorporating new technologies, services, and business models; and (v) ensure the electricity sector is sound and has the proper resources to provide service of quality and meet investment needs.

A recent IDB book has highlighted the trend that the infrastructure sector (and thus power utilities) in LAC is moving from structures to services[3], focusing not only on the investments in hard assets, but also simultaneously on the improvement of efficiencies and new services. In this scenario, utilities will need to alter their business models to adjust themselves: for example, declines in the cost of both solar electricity at small scale (and for some industries, wind) and storage have helped decentralize production and bring added competition to the provision of electricity. While the book identified 4 possible scenarios for the future of electricity, the utilities will need to have efficient operations and be financially sustainable with expertise and resource accumulated to adapt to the new market situation.

The Electrokit focuses on the distribution activities of electricity utilities. Based on the Bank's experience in the LAC region, the distribution and commercialization activities have important areas for improvement as they are the ones mostly impacted by technology disruptions and the growing role consumers have in the energy sector.

The Electrokit builds on the opportunities identified in the Energy Sector Framework (ESF)[4] to improve performance of public utilities following the unbundling of the electricity sector in LAC that happened in the period 1980-2000s which increased competition along the value chain. This new competitive environment has led public utilities to develop plans to strengthen their corporate governance structure as well as seek ways to improve their operational efficiencies. Moreover, the ESF has identified the need to modernize the public sector incorporating new technologies, and promoting the adoption of innovation, and not only to smooth potential disruption these innovations could bring, but also to incorporate these into their operations.

The benefits of electricity distribution companies using this toolkit are: (i) have access to a comprehensive framework that consolidates the most important processes of a distribution company; (ii) review the company's practices and performance against a set of industry best practices and benchmarks; (iii) advance the analysis with the use of case studies and how other utilities are actually improving their performance and (iv) develop implementation plans with items that have the largest impact on the quality of their services and on their financial sustainability.

The next chapter presents the structure of the Electrokit with a standard approach to review the indicators and practices of each activity.

[3] IDB From Structure to Services – The Path To Better Infrastructure in Latin America and the Caribbean (2020). Edited by Eduardo Carvalho, Andrew Powel, Tomás Serebrisky. Accessible at: https://flagships.iadb.org/en/DIA2020/from-structures-to-services

[4] IDB Energy Sector Framework Document – Energy Division (October 2018). Accessible at: https://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=EZSHARE-715548541-11

2. Structuring the practices in the electricity sector

2.1 Main structure

In the context of the use of the Electrokit, the main activities of a typical electricity utility have been organized in four areas. Individual areas are broken down into sub-areas, which are further broken down into activities. Figure 2 illustrates this hierarchy. This organization is based on reviewing similar instruments and the four areas is an attempt to aggregate the activities and processes of the distribution of electricity services in a consolidated and clear manner to facilitate the analysis and implementation of the toolkit's activities.

The first area encompasses the technical and operational activities such as the provision, quality, and reliability of the electricity services, including the level of access and the efficiency in the provision of services. These are mostly related to customer service activities and this area is considered part of the core activities of a utility. The second area is related to the financial, organizational, and corporate governance activities which have dedicated literature and practices for their activities but are not very different from other regulated activities. A similar structure is used for the third area of environmental, social and resilience activities of an electricity utility. Finally, the fourth area of innovation deals with the activities that utilities need to prepare themselves to manage disruptions, technology changes, and development of new business models. In the case of SOEs, advancement in this last area will be dependent on the availability of financial resources as some of them face financial restrictions. Each of these areas is broken-down in subareas and activities and they are further described next.

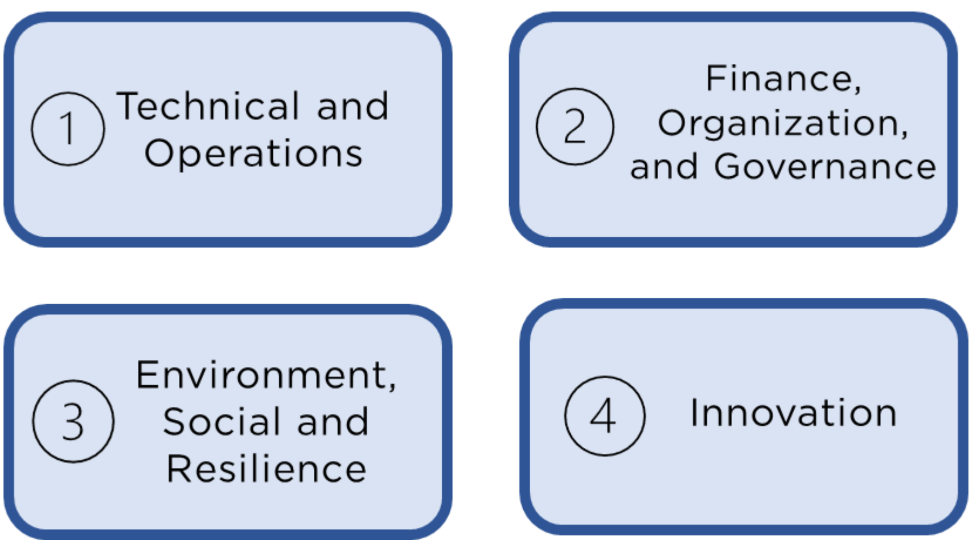


Figure 2 - Four main areas

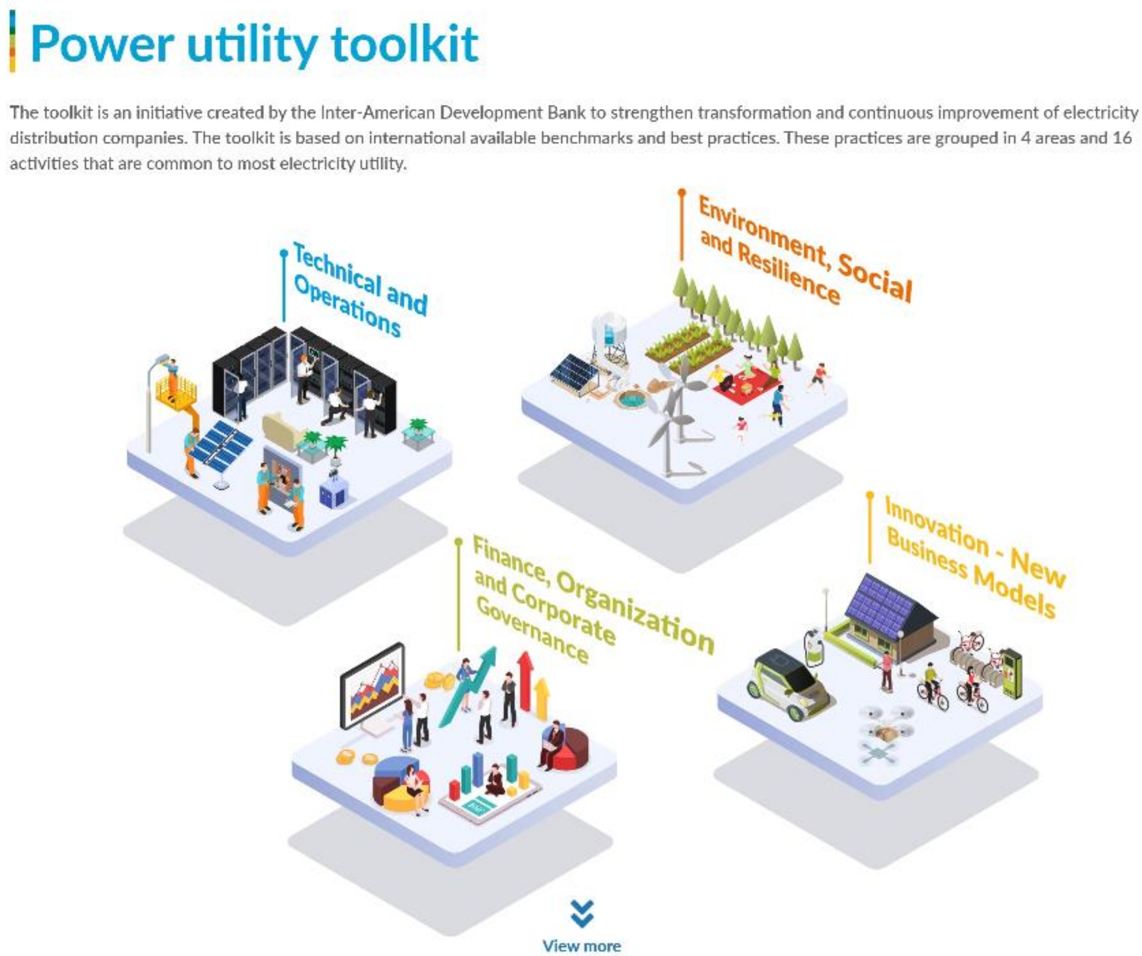
While the analyses of the toolkit focus on the current situation of the utility, when analyzing the performance indicators, it is important to consider the previous 3 to 5 years (depending on the subarea) as time horizon of the analysis to identify trends and avoid analysis of outliers.

2.2 Structure of areas, subareas, and activities

Areas	Subareas	Activities
1 Technical and Operations	Efficiency in Operation (EO)	• **Electricity loss reduction** • Management of O&M costs
	Quality of Service (CS)	• Quality of the Technical Service • Attention to the client
	Access (AS)	• Access to service
	Efficiency in Investments (EI)	• Efficiency and execution of the investment plan and asset management
2 Finance, Organization, and Corporate Governance	Financial Sustainability (SF)	• Financial management and sustainability • Commercial management
	Corporate Governance (GC)	• Autonomy, decision making, controls, and transparency. • Strategic planning, organizational structure and Human Resources (HR)
3 ESR	Environmental, Social and Resilience (ES)	• Climate change mitigation • Environmental and social aspects • Resilience and emergency planning
4 Innovation	Innovation and Vision of the Future (IN)	• Technology, digitalization and cybersecurity • Modernization and vision of the future • Innovation Initiatives

Figure 3 - Areas, subareas, and activities

This structure of areas and activities will be presented in the web platform using the following visual representation:



The first area related to the technical and operational activities includes the core actions of a distribution company and it is subdivided into six main activities:

1. **Electricity Loss Reduction** – Assesses the degree of productivity and efficiency of the transmission and distribution systems of the utility. It analyzes indicators and benchmarks and introduces best practices when designing a comprehensive plan to improve the technical and non-technical (commercial) electricity losses.

2. **Management of O&M costs –** Reviews the operation and maintenance (O&M) costs of the utility to assess its efficiency and optimal costs of operation with a focus on the transmission and distribution. The analysis and benchmarking of this activity can be relevant to the determination of the electricity tariffs, as depending on each country situation, the regulators may establish the specific references and targets.

3. **Quality of the Technical Service –** Measures the reliability, continuity of supply, and the voltage quality of the electric system using a set of standard metrics. Overall, it relates to the ability of the electric system to perform its functions, measuring indicators such as SAIDI (System Average Interruption Index) and SAIFI (System Average Interruption Index)

4. **Attention to the client** – Assesses the interaction between the service provider (distribution company) and the user on services such as responsiveness to customers, billing information, service disruptions, and handling complains. Main objective is to provide best and most responsive service to the customers.

5. **Access to service –** Describes how the utility is supporting national electricity plans to achieve universal electricity coverage, which includes access to remote locations usually in rural areas, as well as those in urban areas with limited access to electricity. It also includes analysis of affordability of the electricity service to less vulnerable parts of society.

6. **Efficiency and execution of the investment plan and asset management** – Reviews the utility's methodology and process of its investment (financial and operational) plans and the prioritization of projects. Also includes the activities of maintenance of existing assets and the mechanisms the utility have to deal with unforeseen events and shocks.

The second area relates to the financial aspects, organization considerations, and the corporate governance of the utilities. It is organized into 2 subareas and 4 main activities:

7. **Financial management and sustainability** – This activity analyzes the financial health and sustainability of the utility and to what extend its revenues cover the costs and obligations using rations and benchmarks references. It also includes assessment of the balance sheet (e.g., asset register, short-and long-term debt) and remuneration to the capital.

8. **Commercial management** – Assesses the sales and commercial management practices and processes of an electricity utility in activities such as billing and invoicing, collection, and debt management. Also includes management of customer register and internal controls to customer databases. This is an evolving area as with the diffusion of distributed generation (DG), customers are gradually becoming producers in some countries.

9. **Autonomy, decision making, controls, and transparency** – Reviews the main activities of corporate governance of a utility in areas such as accountability, autonomy and transparency, disclosure of information, enterprise risk management, and internal control. Reviews the roles and responsibilities among the Board of Directors, Management, and the other stakeholders.

10. **Strategic planning, organizational structure, and human resources (HR)** – Assesses that a performance management is in place to monitor the utility's

performance in the short and long term, the adequateness of its internal organizational structure and hierarchy, and the aspects of people management. Also reviews and introduces the best practices on the topics related to gender equality, diversity, and inclusion.

The third area deals with the environmental, social, and safeguard (ESR) activities of a utility. It also includes the aspects of resilience and emergency preparedness, and how it is mitigating and adapting to climate change. It is subdivided into three main activities:

11. **Climate change mitigation** – Reviews activities that distribution companies have introduced to mitigate climate change and reduce emissions, with a focus on energy efficiency measures and standards. Also reviews their commitments and activities towards distributed generation (DG) with renewable energy and electromobility.

12. **Environmental and social aspects and safeguards** – Reviews the environmental and social policies, standards, and operational practices of the utility, and their adherence to local and national legislation and international best practices. Reviews also utility's contribution to the Sustainable Development Goals (SDG).

13. **Resilience and emergency planning** – Assesses the preparedness of the utility systems and infrastructure against natural disasters and its contingency plans. Refers to the capacity of the energy systems to cope with the hazardous and external shocks and maintain its essential function.

Lastly, **the fourth area of innovation presents how utilities can transform and modernize themselves,** and it is organized in three activities:

14. **Technology, digitalization, and cybersecurity** – Reviews the initiatives utilities are undertaking to introduce new technologies and increase digitalization of its network and infrastructure to perform new or innovative services while improving efficiencies and reducing costs (e.g., artificial intelligence, predictive analytics, blockchain). Also includes information technology and cybersecurity activities and controls to mitigate its exposure to risks.

15. **Modernization and vision of the future –** Reviews how the utilities are modernizing their activities and considering new business models focused on services to meet future needs of customers, new services and technology disruptions. Also includes the activities of electromobility.

16. **Innovation initiatives** – Considers the level of readiness of innovation culture in the utility, including a review of the internal processes, its ambition and behavior, and resources dedicated to innovation, which can be to optimize *existing* customers or broader to develop breakthroughs). Also includes the partnerships (and the results) the utility has established with leading external organizations to foster innovation.

2.3 Reviewing the activities

This section of the document Electrokit: Power Utility Toolkit – Electricity Loss Reduction presents the structure of the initiative, which will also be available in a web-enabled and digital interactive format. For each activity, the Electrokit will have the following modules ordered as:

- **Overview or Main Concepts** which presents a brief description of the activity,
- **Indicators** provides access to trends, key metrics, and data for the activity. This is the quantitative part of the analysis using external data,
- **Self-Assessment** presents a qualitative assessment of the level of maturity of the utility based on a simple set of questions, with an indicative way to elaborate an action plan,
- **Simulation** presents the functionality for the users to enter their own data and compare their performance with other utilities (available in the web version),
- **Best-Practices** presents the best practices for the activity, including insights that are used as a guide for how other companies are managing this activity and how they have benefited from the introduction of the best practices.
- **Case Studies** lists case studies, methodologies, and technical references in annexes.

The two other modules are: initial Planning activities which include the preparatory tasks to be discussed between the IDB team and the utility before initiating the utilization of the Electrokit. Data gathering is also part of the planning activities; and the final Implementation activities which follow the analysis and action plan and are to be introduced in discussion with the utility. This final stage defines how the projects identified will be implemented, including the governance, the source of funds, and executing arrangements.

The Electrokit is therefore a tool which can be reviewed independently by the utility or in cooperation with the IDB team who can help: (i) identify the opportunities for improvement; (ii) development of an action plan, and (iii) help monitor implementation over time.

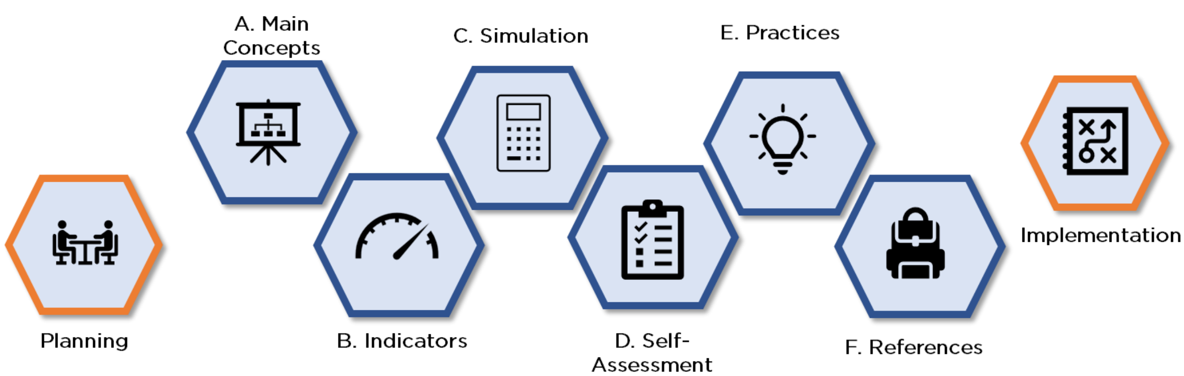


Figure 4 - Electrokit structure

3. Designing an Action Plan

The development of an action plan is an important result from the review of the indicators and best practices for the utility. As an additional functionality of the Electrokit this chapter presents the main tasks to support the identification and prioritization of what are the most relevant practices specific to the utility and what are the best ways to develop and implement an action plan.

The definition of a comprehensive and well thought action plan is essential to attract investment opportunities and communicate the expected results. While there are different methodologies to design an action plan, most of them converge to similar activities, which are presented next as the steps in developing the plan.

Step 1 - Define problem and analyze data.

Action plans usually start by clearly defining the main problem facing the utility and political willingness to address it. This is done by collecting and analyzing the data and verifying previous assumptions of the problems that triggered the review. The Electrokit can be an important tool and methodology to identify areas where the indicators of the utility are below the references, benchmarks, or regulatory standards, and what are the best practices the utility can introduce. It is very important at this step that the leadership presents a vision for the future and its commitment towards pursuing this vision. Still within this first step, usually teams define the targets the utility would like to achieve, which in turn defines the level of ambition of the action plan.

Step 2 - Prioritize activities.

Subsequent to the definition of the problem and expected results, the utility will need to prioritize the areas of intervention. This prioritization is done by segmenting the activities in different dimensions of: (i) impact or effectiveness (i.e., which activities will deliver the highest impacts or benefits – e.g. cost reduction or revenue increase); (ii) timeframe (i.e., what is the best sequence of activities in the short, medium, and long term considering the expected benefits). It is very important to include short wins or quick wins in the timeframe, as it boosts morale of the team and confirms the direction is right; and (iii) efficiency (i.e., based on quantitative measures such as cost benefit analysis, which of these activities will deliver the highest returns for similar levels of investment). Lastly, this prioritization should also identify synergies and complementarities among the activities to be consolidated in a single action plan.

Step 3 - Identify resources.

Based on the action plan previously defined, it will be important for the utility to seek the financial and knowledge/expertise resources, as usually these activities need investments. Some utilities may have their own teams and financial resources to implement the action plan, while others will need to seek external financing and/or bringing technical expertise (example of new technology). Some sources of financing can be concessional with favorable commercial terms, which can make the action plan more feasible to be implemented. In this step it is also important to proactively seek and obtain support from the relevant country stakeholders (e.g., government authority, regulators, industry association, etc.) and clear understanding on the expected impacts and benefits of this action plan.

Step 4. Prepare to implement.

Lastly, the utility needs to develop a detailed implementation plan, not only including the activities previously defined, but also the governance model of the implementation (e.g., definition of team responsibilities and authorities, level of dedication and subordination, etc.) and how progress will be monitored and evaluated. Adaptability becomes a key ingredient of the plan, and an important reminder is to keep into perspective that[5] “a business/action plan can't be a tightly crafted prediction of the future but rather a depiction of how events might unfold and a road map for change”. The results from the readiness to implement, together with seeking political support and securing the financial resources are the last activities before proceeding to implementation.

In sum, this chapter presented in general terms how utilities can develop an action plan and increase the likelihood of successful implementation, using the results from the areas of the Electrokit. The next chapter presents the indicators and best practices of Electricity Loss Reduction.

[5] Harvard Business Review: Updating a classic: Writing a great business plan. https://hbswk.hbs.edu/item/updating-a-classic-writing-a-great-business-plan

4. Efficiency in Operations

This subarea deals with the efficiency in the use of resources of the utility as part of the provision of a public service. Efficiency in the management of infrastructure or of operation and maintenance costs are considered the basic pillars of the area of Efficiency in Operations. This area considers the efficiency in the use of the different resources necessary to meet the standards or quality of service objectives established by the regulatory framework or defined in utilities' strategic planning. The evaluation is oriented to the measurement of the use of the resources in the operation of the infrastructure. The activities covered here are: (i) electricity loss reduction; and (ii) Management of O&M costs. This publication deals with the first activity.

4.1 Electricity loss reduction

A. Main concepts

Electricity losses usually converge to the difference between the amount of electricity that enters the network and the amount that exits the network (final demand consumption and/or energy delivered to other networks). In the case of a utility that it is vertically integrated, the losses represent the difference between its generation injected into the grid and the amount consumed by the final demand. In a few cases, it may include the electricity billed to consumers but not collected after a reasonable amount of time (usually 180 days). This however represents a financial loss in the account receivable as part of the provision for bad debt (or allowance for uncollectable accounts). For the purpose of the Electrokit it is considered an accounting or financial loss (dependent on the accounting rules of each country), and not an electricity commercial loss.

Electricity losses can happen in the transmission or distribution activities. Most of the electricity losses (around 70-80 percent) are related to the distribution end-user activities, as the transmission losses are usually between 20-30 percent of the total. In LAC for example a study estimated that 18% of losses are in transmission while 81% are in distribution[6]. This ratio, however, is not constant when compared to other regions. For example, transmission losses in the USA are around 50% of total losses[7], but these total losses[8] (around 5%) are considerable smaller than the LAC region.

Electricity losses is an important consideration in the LAC region as they represent an estimated financial cost for the electricity industry that ranged from US$11 to US$17 billion in, equivalent to 0.2 to 0.3 percent of the region's GDP. Total losses in LAC are around 17%, while for example in the USA it is around 5%[9]. Estimates from this study indicate that after allowing for a conservative level of technical losses, the percentage of losses translated into

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[6] IDB Power Lost (2014). Refers to the break-down of the 16.9% average loss across 15 LAC countries

[7] Assessment of Transmission and Distribution Losses in New York. THE NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY. The paper refers to two different studies where the transmission losses were 50.3% and 53%. These amounts were over a total electricity loss of 6% and 5.5% respectively.

[8] EAI How much electricity is lost in electricity transmission and distribution in the United States?. Accessed at: https://www.eia.gov/tools/faqs/faq.php?id=105&t=3

[9] IDB Power Lost (2014). Reference 2012

100 TWh lost in, and without substantial reductions in the future, losses can go up to 182 TWh in 2030.

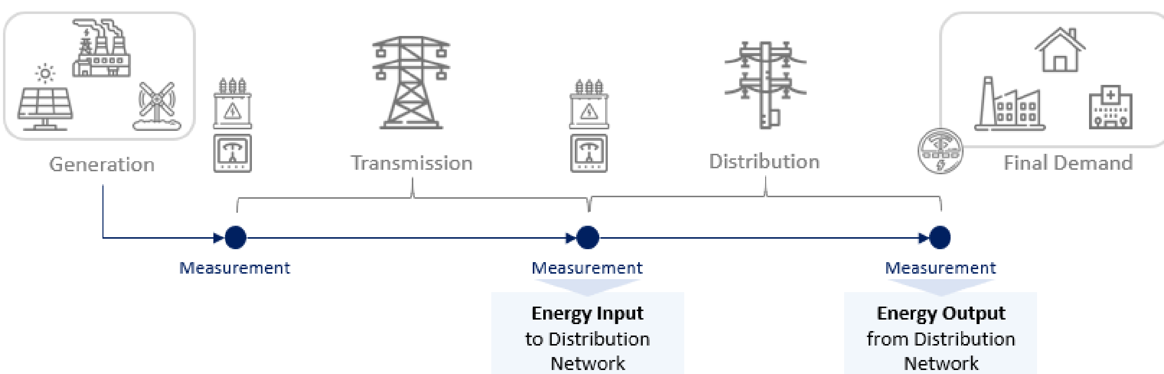
In this context, the reduction in electricity losses brings important financial benefit to the distribution utility but they cannot be an isolated activity. The reduction of losses is usually part of a strategic transformation of the utility with other performance improvement activities as it requires prioritization of investments and allocation of resources. These are described later in the best practice section.

Electricity losses can be divided in two parts:

- **Technical losses**: correspond to all the energy dissipated in the transport of electrical current in conductors, equipment, and connections due to resistance in the distribution network. Technical losses can be further divided into: (i) fixed technical losses (caused by physical inefficiencies such as hysteresis, Eddy Currents losses in the iron core of transformers, and the corona effect in transmission lines) and (ii) variable technical losses (which can happen when power current flows through the lines, cables, and transformers of the network. These are also called load losses, or series losses).

- **Non-technical losses or commercial losses** are those usually associated with the sale of energy supplied to the end user. There is a part of the energy that is produced, transported, and supplied; however, it is not invoiced. These losses can be caused by internal or administrative problems (such as errors in measurement, accounting or record keeping) but they are usually associated with the consumer's own illegal intervention, such as thefts, fraud, alteration of meters, or unmetered supply (when the consumer is responsible).

The following is a schematization of a typical electrical system, identifying the main agents and activities (generation, transmission, distribution, consumption), and the energy measurement along the supply chain.



Based on the above schematization, and in general terms, the energy losses for a distribution system are calculated as follows:

$$Total\ Distribution\ Lossess\ (\%) = \frac{Energy\ Input_{Dist.\,Network} - \ Energy\ Output_{Dist.\,Network}}{Energy\ Input_{Dist.\,Network}}$$

Thus, the calculation of energy losses corresponds to a physical concept and must be consistent with the energy balance of the system:

$$Energy\ Input = Energy\ Output$$

$$Energy\ Output = Energy\ Billed + Energy\ Lost$$

It should be mentioned that the schematic representation corresponds to a conventional configuration of an electricity system, therefore it is important to bear in mind that:

- Due to the development of new technologies and the emergence of new agents in electricity markets, inputs to the distribution system may also come from distributed resources (self-generation, distributed generation, prosumers, etc.), and not exclusively from the transmission grid or large generators.

- Depending on the configuration of the networks, another output of the energy balance may be the delivery of energy to other distribution systems.

- Depending on the country and its regulation, the definition of the transmission and distribution network may vary (definition of voltage levels and the assets that comprise them). Furthermore, in some contexts (i.e., integrated companies), transmission and distribution activities may be considered as a single activity.

In any case, the general concept for the measurement of total distribution losses remains the same: the total energy input to the network minus the outputs, divided by all energy inputs.

It should also be noted that the losses calculation shown before corresponds to total losses, which includes both technical and non-technical losses. Since technical losses are calculated theoretically for each network according to its characteristics (topology, environmental conditions, physical restrictions and inefficiencies, etc.), it is possible to obtain the value of non-technical losses directly by subtracting technical losses from the total losses.

$$NonTechnical\ Losses = Total\ Distribution\ Losses - Technical\ Distribution\ Losses$$

The reduction of losses is a key activity mainly in the distribution activity. This is because non-technical losses (which are the ones that are subject to be improved or reduced) tend to occur at lower voltages. Energy losses in transmission systems are mainly associated with technical losses at high voltages, which tend to be small, and their efficient level is usually determined by technical analyses.

However, due to the elasticity of demand, the implementation of a loss reduction program can also affect the generation due to the overconsumption. This is due to the electricity "sub-registry" corresponding to the energy consumed by the client that does not circulate through the meter, which is actually reduced from the moment a customer is required to pay for its consumption. By promoting the rational, productive, and efficient use of electricity by consumers, it is estimated that after regularization of the customer, approximately 1/3 of the unregistered consumption does not need to be generated.

At the same time, the regularization of electricity services improves the wellbeing of customers as residential consumption of modern energy sources is correlated with per capita income[10]. The regularization of services also enables the possibility of using electricity for productive activities and further economic development.

Based on available methodologies and definitions, it is possible to calculate the indicators of electricity losses by country, utility, and further segmentation by geography based on the availability of data. Whenever possible these indicators must consider the distributional impact of the losses, in particular to those parts of the society which are more vulnerable and have less resources.

Lastly the assessment to develop an electricity loss reduction program needs to acknowledge that the level of effort and activities would be different depending on the level of losses of the utility. For illustration purposes, in 2019, Brazil had an average electricity loss of about of 14% but the individual losses across the 78 utilities ranged from 3.9% to 47.4%. The wide dispersion at country and regional levels exemplifies that the starting point for each country is different and therefore the activities selected have to be tailored to each country (and utility) situation.

For example, for countries with high electricity losses (greater than 20% for example) there is the need for the utility to collaborate more with national authorities revising if there is proper legislation and regulation to reduce losses. Moreover, within this group representing high percentage of losses, utilities need to develop social and affordability programs to transfer a large part of the customers towards regular services. Conversely, in the situation where electricity losses are very low (for example lower than 8%) the loss reduction program should focus on technology advancements. It is against this backdrop that the Electrokit of electricity losses presents a menu of best practices in each of these key areas, to be identified and selected as per the actual situation of each utility.

[10] How do households consume Energy? Evidence from Latin America and the Caribbean (2020). Raul Jimenez Mori and Ariel Yepez-Garcia. http://dx.doi.org/10.18235/0002874

B. Indicators

The IDB has an established track record of providing tools and instruments to support analysis, help plan infrastructure investments in the LAC region, and speed-up their deployment. These tools, jointly developed with international partners, aim to overcome the limited availability of data as the current information, in addition to being scarce, tends to be outdated, incomplete and low quality by international standards.

This section provides an overview and quantitative analysis of the electricity losses in the LAC region. The main messages of this analysis are:

- **Electricity loss is a key challenge for the electricity sector in LAC**. On average, around 15% of the electricity generated in LAC is lost (through technical and non-technical losses). The cost of electricity losses was estimated to be more than US$ 35 billion (2018). Around US$20 billion could be avoided if the LAC region achieves the losses of the most efficient countries, like Chile in LAC or an average European country.

- **In the short term, it is urgent to tackle the problem of losses as it is a burden for electricity distributors in many countries**. In the long term, the region should move forward standards and best practices of developed countries (such as European countries or the losses that are already observed in Chile). In doing so, the region can deliver higher benefits for consumers and for companies.

- **There is large heterogeneity on electricity losses among and within countries**. There are distributors with losses similar to developed countries (bellow 4%) and companies with losses superior to 1/3 of the whole demand (higher than Sub-Saharan Africa). The inequality within the countries shows that, until now, national regulations and policy makers have not been able to drive a convergence in practices and results for electricity losses.

- **In the last decade, there is no substantial improvement in the electricity losses in LAC.** It indicates that there is still room for improvement and an opportunity for companies, regulator and policy makers to improve the electricity services (affordability and quality) by focusing on how to decrease losses by considering broader factors such as the social and cultural factors behind them, and the benefits of introducing new technologies for example.

Introduction

Electricity losses are characterized by the difference between the electricity injected in the network and the electricity sold to the final consumer. The losses can be grouped into technical and non-technical losses. The technical losses are impacted by the topology, the net length, materials, equipment used and the load behavior (balance, load factor, demand maximum permissible loading level, etc.). Besides the technical losses, commercial losses are critical components of the total losses, especially in some companies in LAC.

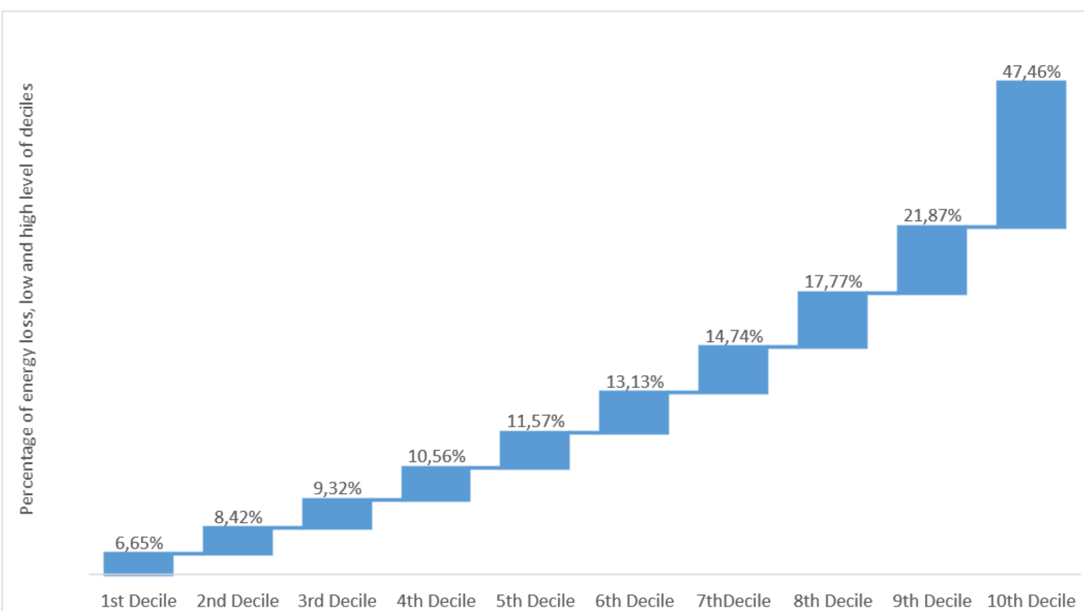
This section analyzes the current situation, and the historic evolution, of electricity losses in distribution companies in LAC (from now on called utilities). This analysis is based on publicly available information of the utilities in LAC summing up a total of 183 utilities in 17 countries between 2008 to 2020. The amount of information for each utility varies over the years. The total number of utilities from 2008 to 2019, per year vary between 60 (in 2020) and 176 (in 2017). At the time of writing, 156 utilities have available information about losses in 2019. An additional comparison is made with international countries, where the percentage of losses from 29 European countries was selected and compared with countries' data available at OLADE database.

The analysis was organized as follows: (i) current state of electricity losses in the LAC; (ii) evolution of electricity losses by utility in LAC; (iii) cases of success and non-success regarding the reduction of electricity losses in LAC; (iv) analysis of technical and non-technical losses in LAC; (v) comparison by company type (private and public); (vi) international comparison; and (vii) electricity loss costs.

Current state of electricity distribution losses in LAC

The average of the total electricity losses in utilities in LAC in 2019 was 13%[11]. However, the dispersion is remarkably high: there are companies with losses with more than three times higher, achieving 47% of losses, as well as distributors with results lower than 4%.

Figure 1 LAC Distributors Electricity Losses per Deciles (% in 2019)



Source: Own elaboration with IDB data

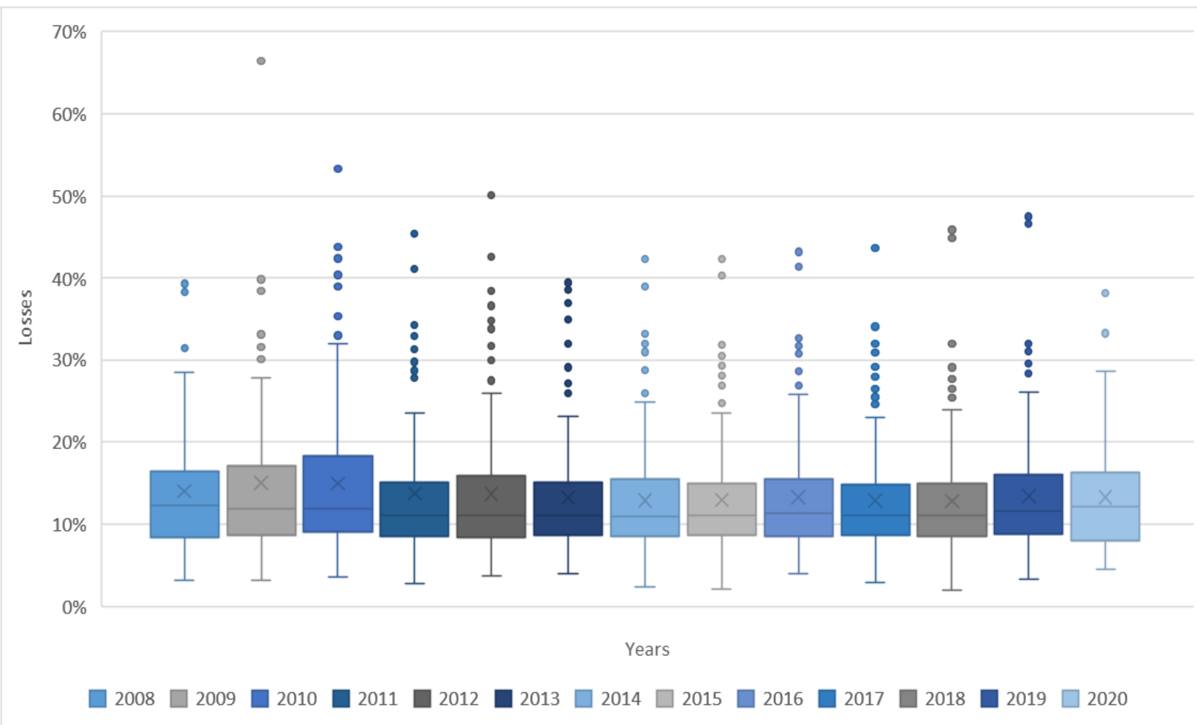
[11] The 13 % average is different from average of the total losses at national level published by OLADE (15%). The first data consider utilities with available data. While the second data is based on national declaration of total electricity losses in the system for LAC countries.

The graph above represents the distribution of the results of electricity losses for utilities with available public information of LAC in deciles for the year 2019. For example, the first decile contains 10% of the most efficient companies, while the tenth decile contains utilities with 10% of the worse results. The analysis indicates that the 10% of the companies with the best performances had losses lower than 6,65%. On the other hand, 10% of the companies with the worst results have energy loss between 21,87% and 47,46%. The 10th decile shows the largest variability among the deciles. The variation in the amount of energy losses concludes that there is heterogeneity in the results of the utilities. Added to this the differences in energy losses within countries, it is possible to say that the heterogeneity is not just regional, among the countries, but also among utilities within the countries.

Evolution of electricity losses in LAC

Electricity losses in LAC from 2008 to 2020 have maintained, on average, a stable pattern, without significant changes. The following graph shows the compilation of the annual results of total electricity losses for the utilities in 17 countries with public data n LAC, namely: Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Ecuador, Guatemala, Guyana, Jamaica, Mexico, Panama, Paraguay, Peru, Dominican Republic, Trinidad and Tobago and Uruguay.

Figure 2 Dispersion of LAC Electricity Losses in Distribution Companies % (2008-2020)



Source: Own elaboration with IDB data

In the previous boxplot, the line that divides the rectangles are the medians, the X the mean, and the box represents the dispersion, also called interquartile range (IQR, which is the difference between the first quartile and the third quartile). Multiplying the IQR by 1.5 results in the external dispersion (ED) of the confidence interval. The whiskers of the box represent the confidence interval of the sample. It is defined as the minimum value between the minimum of the sample (S) and Q1 less ED. This is Min Value = Min (Min (S), Q1-ED). Conversely, the maximum value is the minimum between the maximum of the sample and Q3 plus ED. This is Max Value = Min (Max (S), Q3+ED). The dot points represent the outliers, these are the utilities with levels of energy losses above or below the confidence interval.

In general, LAC utilities have maintained stable their electricity losses between 2008 and 2020, presenting a homogeneous pattern without substantial changes in their loss levels. Despite some oscillation in the dispersion of data, it is possible to see that the mean and median have shown minor variation over the years. On average, over the years, the median of electricity losses has stayed between 11%-12%.

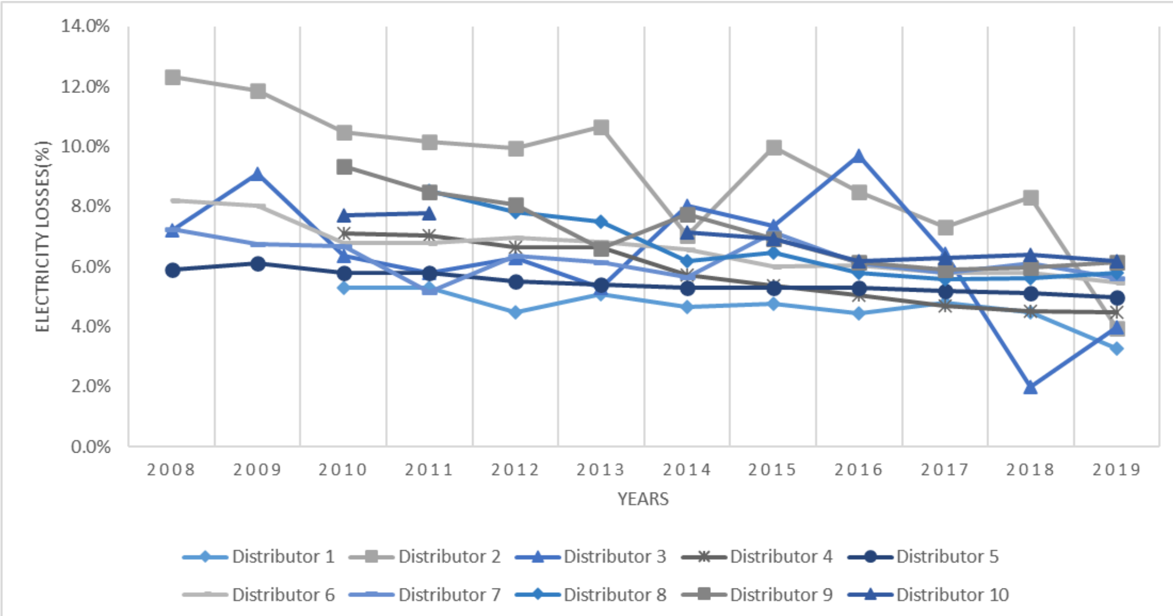
The chart also illustrates the presence of outliers on the upper limits every year, that can impact the accuracy of the mean, and contribute to an asymmetry of the median in all years, resulting on a bigger dispersion of data in the third and fourth quartiles than in the first and second quartiles. The presence of distant outliers reveals the low performance of certain utilities that have a level of loss much higher than the others. However, compared to 2008 and 2009, there is a slight improvement in performance, given that in those years the companies with the worst results had more than 50% of electricity losses.

Success and non-success cases in LAC

The analysis of the companies in the next chart presents the losses of the companies in the first decile of the distribution, that is, the top 10% with the best results. In 2019 there was a group of companies with particularly superior performance on electricity losses, which have consistently improved since 2008. The utility with the best result in 2019 was the one with the highest level of improvement within the utilities in the first decile as it had the highest losses of the first quartile in 2008. This demonstrates that even the best performers can still improve their condition. Some of the other utilities were already well placed in 2008 and kept their positive performance.

The behavior of the ten companies with the best results can be grouped as follows: (i) four showed high oscillation over the period and significant improvement in the last years; (ii) four continued to improve continuously; (iii) two showed a constant trajectory of improvement, but in recent years they have faced a small increase in their losses.

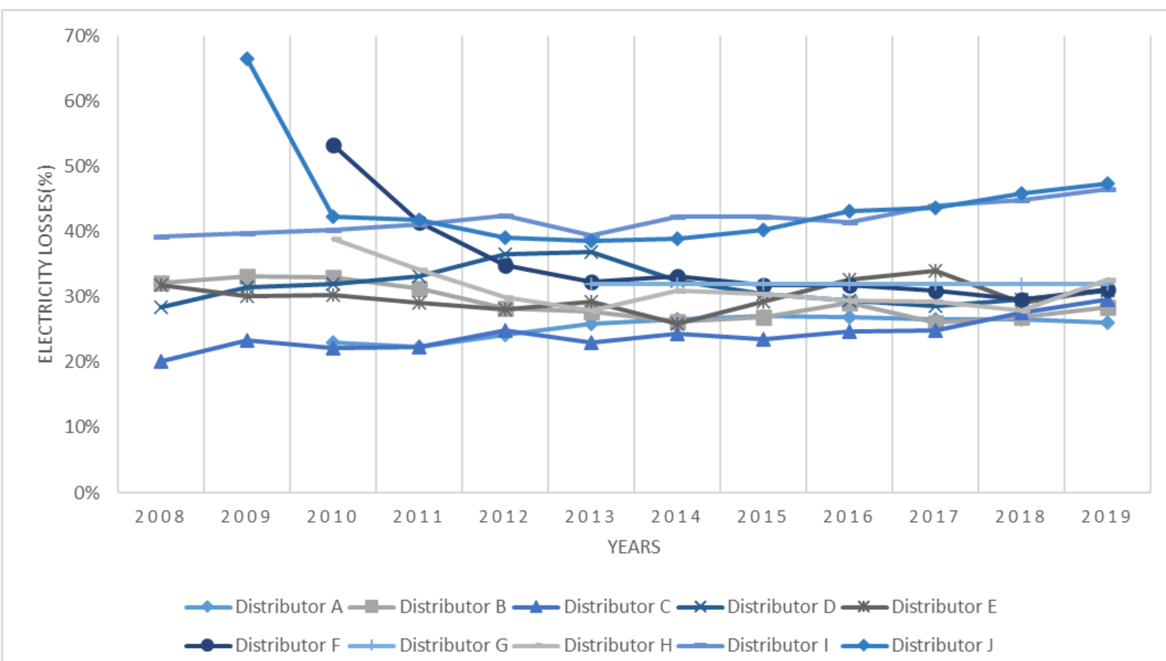
Figure 3 Evolution of Total Electricity Losses: The Distribution Companies with the 10 Lowest Losses (%, between 2008-2019)



Source: Own elaboration with IDB data

The behavior of companies located in the tenth decile, (i.e., the companies with the highest level of losses), have not significantly improved in the last 12 years. Such information is presented in the next chart.

Figure 4 Evolution of Total Electricity Losses: The Distribution Companies with the 10 % Highest Losses (%, between 2008-2019)



Source: Own elaboration with IDB data

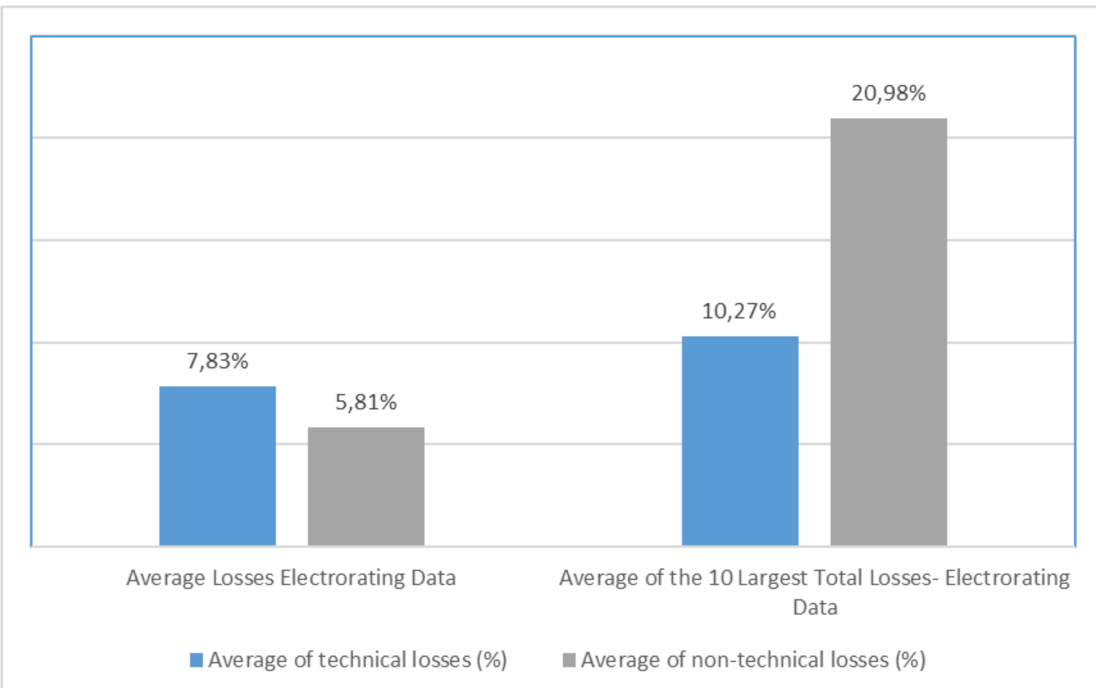
Of the companies with the worst results, the pattern of losses occurred as follows: (i) two maintained the position around the average of yours results; (ii) Three achieved improvements but still continued with high levels of loss; (iii) four showed a constant worsening in its results(iv) One maintained the results throughout the period.

Although some companies are experiencing an improvement in the 10th percentile, the tendency is that the companies with the worst results remain in this position, demonstrating the difficulty of companies in this situation to achieve better levels of energy losses.

Technical and non-technical losses

As previously mentioned, the losses can be divided into technical and non-technical, which makes it possible to understand which factor has the greatest weight in electricity loss. The following is a graph with information regarding the result of electricity losses in distributors in Brazil, and Ecuador divided by type of loss.

Figure 5 Technical and non-technical losses (%): LAC distributors (2018)



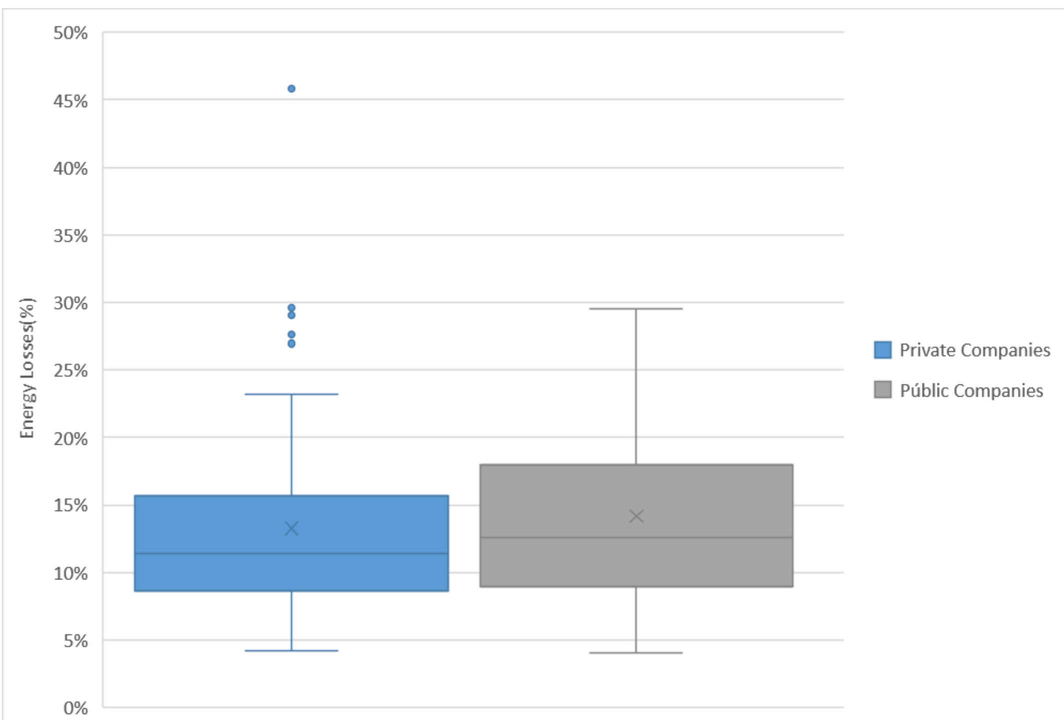
Source: Own elaboration with IDB and data

The simple average[12] of technical and non-technical losses for a group of 88 distributors are 7.8% and 5.8%[13], respectively. It means, on average, the non-technical losses tend to have smaller weight. However, for the utilities with higher level of losses, the non-technical losses tend to be the biggest problem. When considering the utilities with the highest total losses in LAC, the average technical losses is 10.2% and a non-technical loss 20.9% (more than three times higher than the average).

Comparison by company type

For the distribution companies analyzed in 2018 in LAC, 67 were private and 34 public. On average, private and public companies have similar energy loss levels (13% and 14%, respectively). Concerning the dispersion of losses levels, the interpretation differs depending on the outliers. On the one hand, if we exclude the outliers, public companies have a larger dispersion of losses levels. On the other hand, if we include the outliers, private companies have a larger dispersion of losses levels.

Figure 6 Comparison of Energy Losses of Private and Public Distributors (%, 2018)



Source: Own elaboration with IDB data

[12] The average energy losses weighted by sales in GWh was approximately 8% and 6.5% for technical and non-technical losses, respectively. These values are close to the simple average, which was used due to the greater availability of data, 79 distributors, as opposed to the weighted average, which had data from 45 distributors.

[13] The average performed with CIER data poins to a result of approximately 7.5% and 5,1% for technical and non-technical losses, respectively. Source: Indicadores de Calidad de Servicio en Empresas Distribuidoras de Energia Elétrica. Accessed in 01/29/2021 in: https://www.cier.org/es-uy/Lists/Informes/CIER%2006%20v2019%20cod%20VF.pdf.

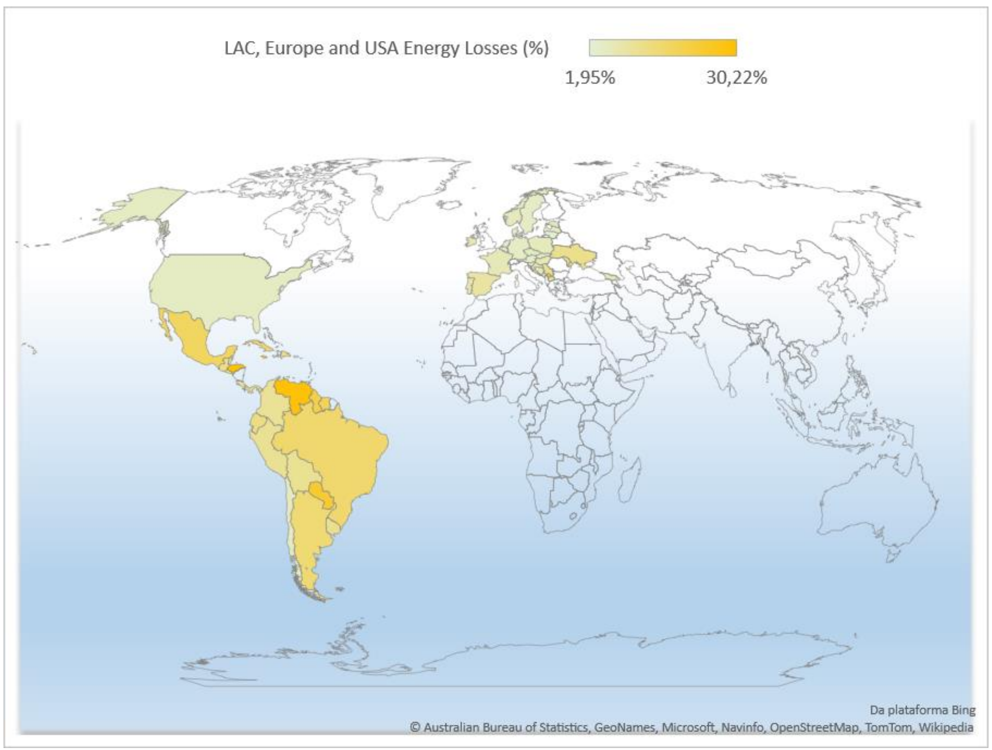
In the boxplot, the rectangle contains 50% of the cases, the line that divides the rectangles are the medians, the X the means, the lines the maximum and minimum values, the points the outliers. Outliers are defined using the standard box plot calculation.

The analysis of the graph shows that 50% (Between the lower limit and the median) of the private companies with the best performance, in general have a result superior to the 50% best public distributors, where the private companies have a variation of results between 4 % and 11% and the public companies between 4% and 13%. The simple average shows a slightly better result for private companies, which had an average loss of 13.2%, while public companies had 14.2%. It is worth noting the presence of outliers in the private companies group, which increases its average energy loss. The average of private companies without the outliers is 11.5.

International Comparison

In addition to the analysis of electricity distributors in the region, it is valid to consider how LAC countries total electricity losses can be compared with other countries with best practices in place. This section compares the LAC data with European countries.

Figure 7 National Average Electricity Losses: LAC, Europe and USA (%, 2018)



Source: Own elaboration with data from OLADE, CEER, EIA[14]

[14]Source:2nd CEER Report on Power Losses. Accessed in 01/29/2021 in:
https://www.ceer.eu/documents/104400/-/-/fd4178b4-ed00-6d06-5f4b-8b87d630b060
https://www.eia.gov/tools/faqs/faq.php?id=105&t=3

The analysis of the previous graph allowed us to observe that, in general, the countries of Europe and the USA have much lower average electricity losses. Moreover, the graph illustrates the heterogeneity between the results of the countries in LAC. It shows that some LAC countries, such as Chile, have better results than European countries like Spain, Portugal, and France. Moreover, observing the LAC utilities in 2019, the top 10% had energy loss levels below 5%, which puts them close to the levels of the best international practices. However, the other LAC countries have levels of energy loss ranging from 9,79% to 30,22%, which is where it is placed most of the distribution companies.

Electricity losses costs

The estimated cost of energy losses at LAC, considering the total losses was higher than US$ 36 billion in 2018[15]. However, it must be considered that some level of loss is inevitable and expected, as stated in ANEEL (2019). Thus, to calculate the costs that could be avoided by improving the efficiency, it is necessary to discount the levels of expected losses[16]. If we use the average losses of European countries as a reference for a long-term objective, the losses costs that could be avoided in ALC is superior to 20 USD Billions, estimation as described in the table 1.

Table 1: Information for Estimating Costs (2018)

LAC-Total Electricity Supply 2018 (GWh)	1,631,043
LAC Total Energy Losses 2018 (%)	15,88%
Average Total Energy Losses in Europe 2018 (%)	6,76%
LAC Losses Above Efficiency Level (MWh)	148.751.142,7
LAC- Cost in US$	$20.924.823.249,42

Source: Own elaboration with data from OLADE[17], and CEER[18].

[15] We estimate the costs by using the lower level of tariffs "the industrial electricity tariff". As we do not know how much of the losses is associated with each time of consumer, we defined the value based on the lower tariff to be able to affirm that the losses estimations is higher than 36 US billions. Using the residential tariffs (the highest level) the losses cost estimation would sum up to 41 US Billions. LAC Energy Price 2018 (US$ / MWh) - Industrial Tariff $140,67; LAC Energy Price 2018 (US $ / MWh) - Residential Tariff $160,24; LAC Energy Price 2018 (US $ / MWh) - Commercial Tariff $151,80, data from OLADE.

[16] (Jiménez, 2014) estimate the cost in monetary values of the losses of electricity attributed to inefficiency (and non-technical causes), discount a level of reference losses from the actual losses.

[17] Source: HUB DE ENERGÍA AMÉRICCA LATINA Y EL CARIBE. Accessed in 02/04/2021 in: https://hubenergia.org/en/indicators/electricity-losses-percentage-total-electricity-supply# And https://hubenergia.org/en/indicators/evolution-electricity-rates-latin-america-and-caribbean

[18] Source:2nd CEER Report on Power Losses. Accessed in 02/04/2021 in: https://www.ceer.eu/documents/104400/-/-/fd4178b4-ed00-6d06-5f4b-8b87d630b060

For the calculation of the cost of electricity losses in LAC that could be avoided in long term, we used the European average as the best practice for reference. The European countries with data made available by CEER, have an average loss of approximately 6.76%[19].

In 2018, the total electricity supply in LAC was 1,631,043 GWh and the total regional losses were 15.88%. When considering 6.76% as a reference long term parameter, the total energy loss above this value is 9.12%, giving a total of 148,751 GWh of energy losses. Considering the 2018 industrial tariff ($ 140.67), the total value of the avoidable cost of losses at LAC in monetary amounts was approximately $ 20 billion.

With less ambitious goals in the middle term, Jimenez et al 2014, suggest that 10% of non-technical losses could be an achievable goal for developing countries. Using this value as a benchmark, the costs of avoidable losses in LAC would be around 13 USD billions. It is important to note that value is an estimative, and the efficient amount of energy losses varies between regions, countries, and cities. Appropriate benchmark methodology needs to be carefully considered for precise values this allows us to have an aggregate idea of the problem.

Another way to illustrate the problem is analyzing the Brazilian case, it is the largest country in the region, and it is responsible for around 50% of the electricity losses in LAC. When considering just the losses in the distribution system, the regulatory agency ANEEL allows part of the losses to be recovered by the distributors companies (what is called regulated losses) and part of it is a cost that the electricity distributors do not recovery, therefore becomes a company loss. In 2019, the losses that consumers paid in their tariffs when remunerating electricity distributors was around 3.5 USD billion[20] which represented more than 8% of the consumer tariffs (ANEEL, 2019). Moreover, in Brazil there is an increasing part of the loss which is not remunerated through tariffs and become distributors companies' losses (around US$ 0,5 billion in 2019).

We could interpret the difference of the potential of avoid losses in the short and in the long-term perspective. In the short term, it needs urgent transformation as it is already an important financial loss for the electricity distributors in many countries. In the long term, we should move forward standards and best practices of developed countries (such as European countries, United States and Chile), and if it is so, we can expect much higher benefits for consumers and for companies itself.

[19] This is a weight average based on the losses of each country weighted by the demand of each country.

[20] We use USD/Real exchange rate of 0.24, it means 14,8 Billion of Brazilian Reais.

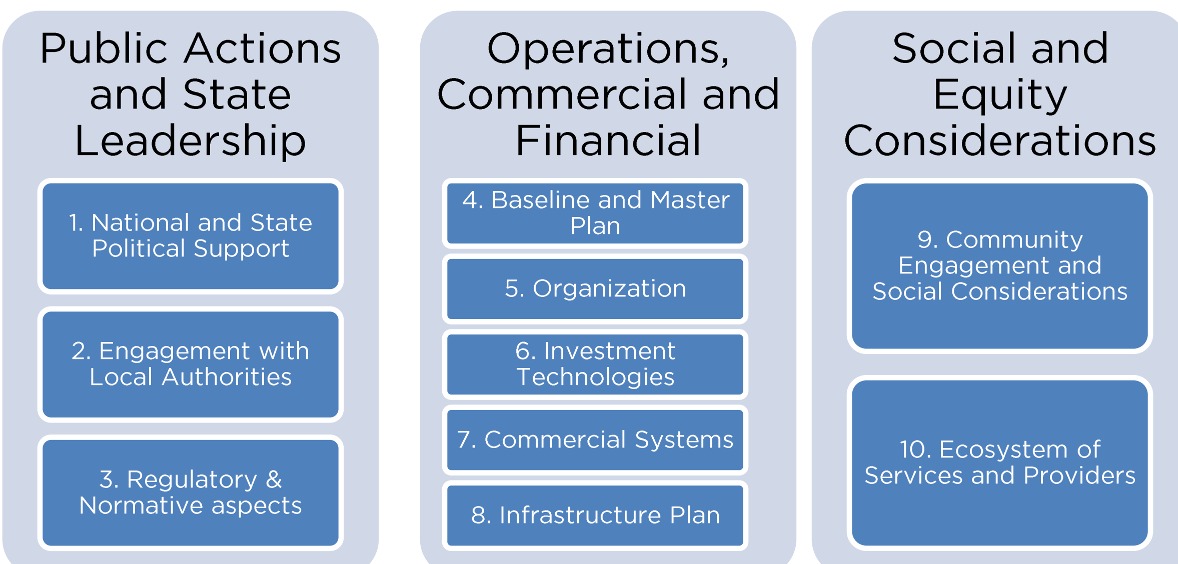
C. Best practices

The best practices presented below stem from the objective of the Electrokit which is to support electricity companies identify performance improvement opportunities considering the relevant participation of SOEs in the LAC region. In this sense, the best practices approach consists in identifying de main fields of improvement and their associated activities, rather than to enunciate and describe specific projects and practices that could be suited for particular cases.

International experience in the management and reduction of electricity losses indicates that a company must have a "holistic view" of this activity since it integrates several units, and the results have a large impact on its financial and operational results. The LAC region has implemented successful electricity loss programs, and some of these are illustrated in the next section of references. Considering the indicators calculated for a company compared to **external references, and the good practices described below, it is possible to establish an** action plan with the activities to reduce electricity losses.

For each practice, the main "insights" found in companies that have been successful in this field are listed. These insights are not authoritative, since each company must adapt the practices to its reality, however they serve as general guidelines to assist the company to advance its respective good practice.

The practices of electricity losses are organized in 10 items across three main groups which are presented next: (i) public actions and State leadership; (ii) operations, commercial, and financial practices part of a distribution company (core part of the activities of a distribution utility), and (iii) social and equity considerations.



Public actions and State leadership

1. **Obtain political support with government authorities and promote awareness for the introduction of a loss reduction program.**

   Successful programs have usually been associated with a preponderant role of government authorities to tackle the challenge, where public utilities regularly report progress to senior government authorities. In this regard, the formulation by the government of a policy framework on the adoption and remuneration of a utility loss reduction plan need to be regulated by the regulatory authority, as was the case in Colombia (see in D References section Resolution CREG 015 – 2018).

   In the end, all of the above has to do with the financial viability of loss reduction programs, which may have different financial sources such as contributions from the national budget, reimbursable multilateral bank loans (which are finally paid with the budget of the nation), and rates. The way in which these sources can be combined makes part of the strategy to be adopted by the Government. The selection of new investor operators who have the responsibility of the total management of the distribution, including the investment in reducing losses, expansion, and replacement of the electrical infrastructure, may also be part of the aforementioned strategy.

   While this is not a direct action by the distribution utility, political support is key to reducing electricity losses, in particular, with large commercial and industrial customers. In some cases, a dedicated and transparent budget is established to manage the transition of certain residential customers with low consumption. Some countries have provided this support in the form of targeted subsidies to customers with low consumption (such as less than 100 kwh/month, but this is country specific). This budget support to targeted customer needs to be properly estimated and defined its duration.

   In addition, and as part of proactive activities the utility can, in collaboration with the government: (i) foster development and implementation of energy efficiency standards, and (ii) promote new materials and construction standards with local and national governments, such as the use of solar heating, thermal insulation of roofs and natural and efficient lighting.

2. **Promote awareness and establish partnerships with local control authorities such as local police and law enforcement to take prompt action in the event of theft when amicable and commercial resolution is not possible.**

   These actions are particularly important on commercial losses in the industrial and large commercial segments as a few clients can represent a large value of the losses. Utilities should enforce compliance with the law and its judicial processes in the cases and eventually consider executing criminal proceedings for theft or fraud of electricity. The collaboration with local authorities must be adequately documented and transparent.

The introduction of informational campaigns to improve visibility of the program and the payment culture is also an effective measure. The utility and authorities can promote journalistic coverage of actions to combat non-technical losses to positively influence the culture of paying the energy bill. It is also important to give visibility to the authorities of the economic impacts of losses, reinforce transparency, and bolster the aspects of zero tolerance to mal practices.

3. Regulatory and normative aspects.

Utilities can engage the regulatory authority to ensure the proper incentive mechanisms to unlock energy loss reduction are in place. This includes discussion with the regulators to identify impacts in the calculation of electricity rates in such a way as to allow affordability to the most vulnerable population. Also, it is important to review if supply or grid codes are incentivizing loss reduction.

In addition, and in collaboration with the regulator, the utility should consider the compatibility of the incentives, as these have been determinant factors for the reduction of losses[21]. These include: (i) establish rate loss limit. A non-technical loss limit value can be attributed to the rate, since the company will not be able to absorb all the economic loss, but it will have incentives to reduce it over time (decreasing limit); (ii) define the loss limit: determine the regulatory levels of non-technical losses through a comparative analysis, which considers the level of economic and social complexity in a given region (in some cases the limits may be differentiated within regions); and (iii) facilitate technical regularization: in low-income consumers with fraud, allow it to be possible to technically regularize this situation by supplying a standard kit, the cost of which could be financed in installments to be collected in future energy bills.

Operation, Commercial and Financial practices

4. Elaboration of a comprehensive plan and a baseline for the reduction of technical and non-technical losses.

It is essential to develop a loss reduction plan, based on a diagnosis that identifies the baseline, the factors that cause major losses, the definition of strategies to address each field of action, the definition of objectives and goals, the formulation of projects, the definition of an implementation schedule, the assignment of responsibilities in the organization, the criteria for evaluating the plan, and the economic and financial evaluation of the plan.

[21] For example, these incentives were in place in the cases of exit such as in Chile and Peru.

In general, a loss reduction plan consists of three core elements: (i) diagnosis, (ii) identification, design, and evaluation of solutions, and (iii) maintenance of the plan, including its sustainability.

First, a good diagnosis is the determining factor for a well-structured plan and for establishing a baseline. The diagnosis must clearly indicate where, to what extent and for what reason losses are occurring. The analysis of the evolution of these aspects, to the extent that historical information allows, will facilitate a better identification of the set of solutions to be evaluated.

The baseline should distinguish and calculate technical and non-technical losses and their evolution over time with a definition of "as is" – as the present situation. The quantification would be expressed in technical and monetary terms. Due to seasonality impacts, the baseline should be based on minimum of a full year and possible two-year information. This study should be done by specialized and independent firms with the support of the utility's operational team.

Second, the identification of alternative solutions and their contribution to the efficient reduction of losses, evaluated in a comprehensive manner, must respond to a sound technical and economic analysis, based on the diagnosis. For example, if the diagnosis indicates that an important part of the losses corresponds to connection fraud and network tampering, investment in smart metering alone is insufficient.

As part of this identification of solutions, the utility needs to develop a detailed study with a roadmap establishing and prioritizing the activities needed for the reduction of losses. The study must establish a short and long-term action plan with the necessary investments, the origin of the losses (types of consumers and geographic location, if possible, with Geographic Information System -GIS-), a commercial system database, the tools to be used (hardware and software), the goals by period, and a responsible and dedicated team.

Third, the maintenance of the plan consists of crossing information coming from the different metering levels (macro and micro metering to obtain energy balances) with information coming from the commercial area (billing). The result of the analysis leads to strategies and activities (for example, certain types of inspections of users' connections) to be carried out by specialized personnel. Due to the changing conditions of the physical, socio-cultural and market context, the plan must be dynamic.

By way of illustration and according to the particular situation of a given company, some strategies (or good practices, some of them included in this document) may be the following:

a- Correction of current power transformers that measure the energy input to the company's distribution system. It can contribute to significant improvements in technical losses.

b- Adequate management of networks with investments in low voltage shielded networks, reconfiguration of topology, expansion of installed capacity in overloaded substations, etc.

c- Strategic management of brigade contracts by feeders and prioritized nodes for the correction of users' meters.

d- Control of consumptions of major customers and other marketers that sell energy in the distributor's market.

e- Management of new accounts without legalization.

f- Management of public lighting consumption.

5. Organization – Establish a unit dedicated to management and monitoring losses within the utility.

Many loss reduction programs fail due to poor management and ongoing monitoring, both in the technical and commercial components. This is why most programs are accompanied by an activity to strengthen the organizational capacity of the utility, helping to structure a unit responsible for losses and providing the necessary skills and competences. The composition of the unit should be multidisciplinary, and it should have autonomy given by senior management with proper governance arrangements to operate in an agile manner. The unit will provide periodic monitoring and reporting of the electricity loss program against key metrics. In some countries, best practices have also identified the benefit of having dedicated teams for losses in the regulator and ministries for the duration of the program.

However, the mere existence of this unit does not ensure success. Therefore, in addition to its adequate structuring and selection of personnel, it is necessary for the Manager to carry out a permanent evaluation of the operation of said unit, not only based on the activity in the office, but, mainly, on the management in the field where the technical and commercial activities develop.

6. **Prioritize investments in technology and smart metering technologies.**

Investments made to deploy technology tools such as Automated Metering Infrastructure (AMI) or Automated Metering Reading (AMR), supervisory control and data acquisition (SCADA), modern business systems, database management, user access authorization, and exception analysis should be prioritized. These investments should be preceded by cost-benefit analysis that justifies them and demonstrate their contribution to the loss reduction program (since this investment is very expensive, it should be focused on those sectors with the best cost-benefit ratio, for example, consumptions over 400 kWh as was done in Dominican Republic).

Having a system focused on combating non-technical losses and integrating the information available from the client are important steps for the utility to move towards digital transformation, including introducing business intelligence (BI) with tools and resources to perform BI/analytics to identify consumers or transformers with non-commercial losses. Utilities are also using Artificial Intelligence to detect and mitigate electricity losses with Anti-Theft technology. One example is from utility Ampla in Brazil that developed an Anti-Theft Machine Project for medium voltage customers, and it was recognized as one of the top ten innovations of the last decade in Brazilian industry, as defined by *Exame*[22].

Designing a smart metering and technology investment plan that is technically and financially sustainable over time is essential.

7. **Strengthen the commercial systems**.

A commercial system (particularly the one related to the sale of energy to regulated users) is a central element to guarantee the success of a loss reduction plan and its sustainability over time. The commercial system is made up of components such as the responsible organizational structure (company's staff and contractors), software, equipment, as well as the strategies, programs, projects and activities that guide its operation.

At the organizational level, depending on the size of the company and the type of markets served (regulated users, large consumers, etc.), commercial management should be made up of different areas such as commercial operation (facilities management, billing, credit and portfolio management), customer service (face-to-face channels, customer support, design of commercial operations), commercial offers (for large customers) and strategic marketing. Of all these areas, the commercial operation is key to the loss reduction objective, followed by customer service.

Billing and collection are critical activities, that is why utilities have to ensure their billing systems and collection mechanisms are properly functioning and the rate of overdue bills are within reasonable limits of the account receivables. Whenever possible utilities should integrate their CMS with the Network Information System (NIS) so that customers can be automatically associated with a transformer, meter, and location. The commercial systems should also reflect in a transparent manner the support mechanism introduced to socially disadvantageous groups, and this is described later in the social participation practices.

The installation of prepaid energy metering systems in sectors of the population with low and unstable incomes is another element of the commercial system that facilitates the service to this type of customers, by isolating them from the inherent problems to conventional metering systems.

Segmentation of the losses among the residential, industrial, and commercial customers is also an important activity to be performed early on as part of the study. This is because

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[22] Get from reference from IFC article. https://www.ifc.org/wps/wcm/connect/bd3a196d-a88f-45af-bbc6-e0b00790fba8/EMCompass_Note_81-05-web.pdf?MOD=AJPERES&CVID=n72pj5g

losses in the industrial and commercial customers are usually concentrated in few customers with high volume, compared to the residential section which is large number of customers with small volume. Experience has also demonstrated that initiating the loss reduction program with the large commercial and industrial customers can be advantageous.

Experience has shown the importance of making regular checks of personnel that have access to the company's business and billing systems, as well as performing analysis of the data stored in the Customer Management System (CMS). Access to the billing systems and database of customers should be limited as much as possible within the utility, which should carry-out regular audits and verification of who has access to what part of the billing system.

8. **Establish a dedicated infrastructure investment plan in the distribution network and secure resources to reduce vulnerability and adulteration of equipment and connections**.

   Provide modern meter facilities with monitoring facilities and an engineering sector in charge of properly analyzing the technical losses of the system and seeking new technical solutions. The plan should also have a well-established technical loss calculation and quantification methodology based on internationally recognized references or existing national regulations. One of these methodologies[23] to evaluate the cost of loss is provided by "Guide for the Evaluation of Large Power Transformer Losses". Verify the current cost of losses and analyze possible solutions to reduce prioritizing the actions with the highest return for the company, investing in those with a positive net present value (NPV).

   In addition, utilities need to consider, as part of their dedicated energy loss investment plans:

   (i) proper **asset management** processes, having an annual procedure that avoids the misuse of transformers (with very low or high loads), electrical networks, network sectioning, load balancing and the installation of capacitor banks to reduce technical losses.

   (ii) having **shielded network and measurement system** as the application of shielded measurement box with attached telemetry (multiple meters/clients) that prevents clients from accessing meters with remote disconnection, as well as shielded LV networks. Also include anti-theft network configurations using twisted cable in secondary network and bi-coaxial cable in the service drop, which are difficult to tap[24];

   (iii) having **totalizing measurement in the transformer** in pre-selected transformers and feeders. Install a totalizing measurement set to collect monthly readings and determine the energy consumption with the monitored period to determine potential energy loss sites and **using GIS/mapping systems** as these tools help reduce assumptions for

[23] US Department of Agriculture
[24] Technical Note: Advancing Power Sector's Self-Reliance Through Electricity System Loss Reduction.

loss calculations, develop more precise engineering models, and have more accurate results when sampling is not possible.

Identifying and securing financial resources have been critical for the successful development of an electricity loss program. These financial resources, ideally with concessional terms, would ensure availability of investments over time and a link to associated targets. The program would also determine the destination of the additional income resulting from the regularization. Any loss program must be preceded by an economic and financial analysis; and have specific sources of financing for projects and/or supported by public agents in the country. These investment resources can be from multilateral banks with advantageous commercial conditions and long-term amortizations, or from the utility's income and balance sheet.

Social participation and equity considerations

9. **Social participation as part of a soft initiative with the impacted communities, their leaderships and population, with analysis and mitigation of social and affordability impacts.**

Building a positive engagement with the local community is a key ingredient to the sustainability of an electricity loss program. This engagement must be established with the official and non-official leaders of the community and addressing their concerns when implementing the program. In some cases, having the support from Non-Government Organizations (NGOs) can also deliver effective results as these organizations can have proximity to the communities.

As part of the social initiatives, these other items should be considered:

(i) **identification of the main incentives perceived by the population to be regularized**, in order to design the strategy and projects for community participation and socialization of the plan. The above depends on the service delivery environment of the company. For example, in countries where poor neighborhoods have permanent power outages, the promise of good quality and continuous service is a powerful incentive.

(ii) **verify affordability and facilitate access to credit** by promoting financing for the purchase of appliances or solar heating systems. This can be associated with energy efficiency or conservation initiatives on household items, in particular during peak time consumption. Repayment of financing could be associated with the reductions on the value of the electricity bill.

(iii) **strengthen the ability to pay of communities** by promoting new sources of income in poor communities and / or a policy of discount on the electricity bill (e.g., exchange of recycling material in exchange for discounts, training courses and among others).

(iv) introduce **“motivational” products** which is the creation of products that encourage consumers to pay their energy bill, such as insurance, prize draws, discounts on medicines, or discounts on household products and food, and

(v) **consider introducing prepaid systems** as advance payment is one of the most efficient means of enforcing the budget constraint and reducing possible non-commercial losses.

10. Ecosystem of Services and Providers – Establish management of the contracted services.

It is usual for companies to contract with third parties the provision of different types of services, both technical (such as network maintenance) and commercial (such as meter reading conventions, bill distribution, suspension, and reconnection of service), whose conditions of price, quality, compliance with service goals (including penalties), compliance with legal labor requirements and ethical performance are established in the respective contract.

For the contracting of each service, the company must define the contractor's experience and financial support requirements (including compliance insurance requirements) in order to select the best possible option through transparent competitive processes. In other words, it is important to have a well-designed contract. In this field, the experience of efficient companies, especially those controlled by investors other than the government (whether private or public) can be relevant.

As to ensure an efficient outcome of such contracts, it is necessary that they are professionally managed and supervised by a responsible area (i.e., dedicated losses management area or similar, which is associated with the nature of the services provided).

In the case of personnel or crews contracted directly by the company, specific training must be carried out, and draw up an annual plan to improve the design of the training program, as well as to verify its effectiveness. In addition, seek uniformity by conducting talks on the operational bases to unify and standardize the inspection procedure and best practices.

Consider establishing partnership with local inspection companies, promoting the creation of micro-companies made up of people from the community to carry out local inspection and customer orientation, whose payment is a fixed value, maximum value according to the percentage reduction of non-technical losses and percentage of prompt payments.

D. References

For more information regarding the financial management and sustainability, please consult the following references:

Reference	Case Studies	Methodology	Technical Reference
IADB – *Incrementando la eficiencia del sector eléctrico: Lecciones sobre la reducción de pérdidas eléctricas en Ecuador* https://publications.iadb.org/es/incrementando-la-eficiencia-del-sector-electrico-lecciones-sobre-la-reduccion-de-perdidas	✓	✓	
IADB – *Power Lost: Sizing Electricity Losses in Transmission and Distribution Systems in Latin America and the Caribbean* https://publications.iadb.org/en/power-lost-sizing-electricity-losses-transmission-and-distribution-systems-latin-america-and		✓	
A melhora da qualidade do serviço elétrico: A experiência da CEEE no Rio Grande do Sul. https://publications.iadb.org/pt/melhora-da-qualidade-do-servico-eletrico-experiencia-da-ceee-no-rio-grande-do-sul	✓		
USAID Technical Note – Advancing Power Sector's Self-Reliance Through Electricity System Loss Reduction https://www.usaid.gov/sites/default/files/documents/1865/Technical-Note_Loss-Reduction_0.pdf			✓
World Bank Data Base of electricity losses by country. https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS			✓
Banco Mundial – *In the Dark: How Much Do Power Sector Distortions Cost South Asia?*	✓		✓

Reference	Case Studies	Methodology	Technical Reference
https://openknowledge.worldbank.org/bitstream/handle/10986/30923/9781464811548.pdf			
USAID – *Improving Power Distribution Company Operations to Accelerate Power Sector Reforms.* https://pdf.usaid.gov/pdf_docs/PNADJ549.pdf	✓	✓	✓
Best practices in the electric power distribution sector in Brazil promoted by ABRADEE – *Associação Brasileira de Distribuição de Energia Elétrica* through its 42 congres seminar SENDI – *Seminário Nacional de Distribuição de Energia Elétrica* (Anos 2010, 2012, 2014, 2016 e 2018) https://www.abradee.org.br/sendi/	✓		
Best Research and Technological Development Programs in the Electric Power Sector organized by ANEEL – *Agência Nacional de Energia Elétrica* en Brasil mediante su 42ongresso CITENEL - *Congresso de Inovação Tecnológica em Energia Elétrica* (Anos 2013, 2015 e 2017) https://www.aneel.gov.br/programa-de-p-d/-/asset_publisher/ahimI6B12kVf/content/citenel-e-revistas-de-p-d/656831	✓		✓
Best practices and strategies for distribution loss reduction. Final report. (2016). PWC and Forum of Regulators http://www.forumofregulators.gov.in/Data/study/11.pdf	✓	✓	✓
US Department of Agriculture - Rural Utilities Service. RUS Bulletin 1724E-301 https://www.rd.usda.gov/files/UEP_Bulletin_1724E-301.pdf			✓
WorldBank. Reducing Technical and Non-Technical Losses in the Power Sector (Background Paper for the World Bank Group Energy Sector Strategy). https://openknowledge.worldbank.org/bitstream/handle/10986/20786/926390WP0Box3800in0the0power0sector.pdf?sequence=1&isAllowed=y	✓		

Reference	Case Studies	Methodology	Technical Reference
Assessment of Transmission and Distribution Losses in New York State (Final Report). THE NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY. https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Electic-Power-Delivery/epri-assessment-losses.pdf	✓	✓	✓
Regulatory procedures in Brazil, ANEEL – Agência Nacional de Energia Elétrica. Módulo 2: Revisão Tarifária Periódica das Concessionárias de Distribuição, Submódulo 2.6 PERDAS DE ENERGIA. 2015 Technical note from the Regulatory Agency of the Energy Sector of Brazil, ANEEL – Agência Nacional de Energia Elétrica. METODOLOGIA DE TRATAMENTO REGULATÓRIO PARA PERDAS NÃO TÉCNICAS DE ENERGIA ELÉTRICA – AP 023/2014 FINAL. 2014		✓	
Lawaetz, Simone, and Smyser, Connie. Challenges and opportunities in electricity service provision for urban BOP communities. Chapter 7 in Patricia Márquez and Carlos Rufín (eds.), Private Utilities and Poverty Alleviation: Market Initiatives at the Base of the Pyramid. Edward Elgar Publishing, Cheltenham and Northampton, 2011. https://ideas.repec.org/h/elg/eechap/13551_7.html		✓	
CREG (Comisión de Regulación de Energía y Gas – Colombia). Por la cual se establece la metodología para la remuneración de la actividad de distribución de energía eléctrica en el Sistema Interconectado Nacional. See section 7.3 about loss reduction and loss maintenance plans, and the methodology and criteria for their approval. http://apolo.creg.gov.co/Publicac.nsf/1c09d18d2d5ffb5b05256eee00709c02/65f1aaf1d57726a90525822900064dac?OpenDocument&Highlight=0,NoResolucionCREG015-2018	✓		

Reference	Case Studies	Methodology	Technical Reference
CREG - Colombia. Estudio contratado con la Universidad Tecnológica de Pereira (2011): Programa Computacional y Modelo de Estimación del Costo Total del Plan de Reducción de Pérdidas No Técnicas http://apolo.creg.gov.co/Publicac.nsf/52188526a7290f8505256eee0072eba7/f9d31d851f26e52d0525786f0075f81a?OpenDocument – Circulr024-2011 Anexo 1.			✓
CREG – Colombia, Estudios contratados con firma especializada con el fin de establecer las bases para los planes de reducción de pérdidas (2009): 1. Tomo 3 - Pérdidas Técnicas Nivel de Tensión 1. 2. Tomo 7 - Modelo econométrico e inversión en pérdidas. 3. Tomo 7 - Planes de reducción de pérdidas http://apolo.creg.gov.co/Publicac.nsf/52188)26a7290f8505256eee0072eba7/eca47f5da25064ce0525785a007a7202?OpenDocument			✓
CREG – Colombia. Estudio "Insumos para el análisis de beneficios netos de alternativas para implementación de la infraestructura de medición avanzada en el SIN", 2021. http://apolo.creg.gov.co/Publicac.nsf/52188526a7290f8505256eee0072eba7/88177cdd1a416e7a05258679005537e5			✓

E. Annex

Annex 1 – **Key Methodologies Used in Calculation of Transmission Loss**[25]

Various practices are used in the industry to calculate transmission losses. This annex builds on previous work in the assessment of transmission and distribution losses in New York, which mentions the main difference between various methods to calculate transmission losses is the number of load data points considered. As described below, the methodologies range from utilizing one load level to 8760 hourly load patterns for building the power-flow model and calculating the system losses.

- **Peak Analysis –** Run a single coincident peak system load flow and develop loss factors to calculate annual energy losses. This method is used in the industry, but it is not recommended as a "leading practice" due to reduced precision in results compared to other available methods used. Static state estimation can be used in analyzing a snapshot of a single peak load. Peak analysis does not factor in how changing levels of dispatch and transmission system configuration impact flows and losses.

- **Multiple Load Levels –** Obtain seasonal load and resource data and run a number of scenarios with a power-flow model to get an AC solution with loss factors on the appropriate transmission lines and transformers. Integrating information from multiple measurement snapshots can improve results using state estimation. More scenarios lead to more granularity in results but also increase the labor time required to run the analysis. There is a trade-off between the precision expected for the results and the labor burden to conduct the analysis. Usually in loss studies, at least six scenarios are necessary, representing six load levels: peak, minimum, and four intermediate levels for both a summer and winter season, with various levels of generation, as noted in the EPRI Transmission System Efficiency Technology and Methodology Assessment.

- **Analysis of Hourly Load Level Scenarios –** This method involves collecting hourly data points for the loss calculation. This approach generally provides more accurate results. Depending on the source of load data and analysis tools, the following approaches could be used under this method:
    - **Historic Load and Resource Data –** Obtain a full year or several years of load and resource hourly numbers to plug into a power-flow model to get an AC solution with loss factors on the appropriate transmission lines and transformers. The actual data would be best to determine the actual loss that the system had for the year rather than using a shaped seasonality or adjusted peak loss factor.
    - **SCED –** Use specialized software to do a security constrained economic dispatch (SCED) analysis. This analysis utilizes a co-optimized commitment and dispatch algorithm to run an hourly evaluation with a DC flow model. The analysis will have

[25] EPRI: Assessment of Transmission and Distribution Losses in New York. PID071178 (NYSERDA 15464). Available in: https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Electic-Power-Delivery/epri-assessment-losses.pdf

changes in demand and generation, resulting from factors such as time of day and seasonality, and will calculate the annual system losses on an hourly basis:

o Hourly solutions account for transmission constraints as well as N-1 contingency conditions. Intermittent resources such as wind and solar can be modeled with project-specific 8760 hourly production patterns applicable to the region under study. Thermal resources can be modeled with capacity segments and associated incremental heat rates to allow for granular dispatch adjustments. Calculations from the DC flow model can be done using utility-provided load flow transmission system characteristics to determine hourly system losses.

o Due to changes in generation and demand, resulting from factors such as time of day and seasonality, an hourly model is used to calculate system losses. No-load losses can be added to the load losses calculated with the SCED analysis.

o It is important to note that SCED analysis evaluates only real power. Because it is a DC model, only real transmission losses are captured. Loss improvements with voltage/VAR optimization cannot be captured using this type of analysis.

- **State Estimator –** Using hourly State Estimator data, there are multiple methods to determine the system loss factors. The most accurate method is to utilize a modeling platform for analyzing a transmission system. Some models that are widely used include PSLF, PSS®E, and PowerWorld Simulator (by PowerWorld Corporation). The packages for analyzing transmission systems are loaded with the captured meter data, and a state-estimator module in the computer model matches the conditions of the power system in the model to what was measured. Once in this condition, the loss factors can be directly calculated and output from the model:

Using a state estimator, the model is not an exact reproduction of the system. Collected field data and utility staff's knowledge of the system could help in error checking. A solution is considered good when there is a high level of consistency between the estimated solution and actual measured data.

From experience and research, there are three important basic elements needed for successful solutions using a state estimator:

 A redundant, reliable, and accurate measurement set.

 Accurate network topology constructed from the real-time status of switching elements.

 Accurate parameters for the network elements.

- **Actual Measured Data (Without State Estimator) –** Alternatively, if a state estimator is not used, total area load and generation can be modeled for each hour as measured without matching overall conditions, and the loss factors are then calculated. This method provides less precision and requires less sophistication.