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The economics of electricity losses
in Latin America and the Caribbean

Rigoberto Ariel Yépez García
Raúl Jiménez Mori

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Foreword

Latin America and the Caribbean faces persistent challenges in consolidating efficient, affordable, and sustainable energy infrastructure markets. One of the most notable challenges is the prevalence of electricity losses. These losses not only exacerbate deficiencies in service operation and reliability but also erode the income of electricity distribution companies and, in some cases, governments. This situation negatively affects the ability to maintain and expand adequate infrastructure, which harms electrical service quality. The consequences of these deficiencies particularly affect the most vulnerable groups and limit the productivity of economies since these economies fail to offer quality services.

The high levels of electricity losses in this sector have led to significant social, environmental, and economic costs in several countries. Effectively addressing the problems that give rise to these costs involves carrying out a detailed evaluation of losses, determining their causes, and formulating appropriate policy recommendations in the specific context of LAC. This diagnosis is more relevant in the current economic environment with high commodity costs, rising inflation, and moderate economic growth projections.

This book offers an updated perspective on the operation of electricity markets, focusing on the problem of electricity losses. The authors highlight the nature of the problem, its causes, and its operational and financial impacts. In addition, they present solutions to reduce electrical losses and mitigate their impact on society. This book suggests that there are no standard solutions to address this challenge and that the underlying causes need to be recognized, which in many cases may be related to political interference in the management of electric utility companies.

The case studies presented show that strengthening regulatory frameworks, promoting appropriate incentives, implementing new technologies in electricity grids, and improving the management and governance of electric utility companies in the region contribute to reducing and controlling losses. Furthermore, these actions enable the improvement of service quality and reduce greenhouse gas emissions. The implementation of these measures must be done with a long-term perspective, taking into account both short-term and medium-term considerations. To achieve this, it is essential to ensure the commitment of all parties involved, including consumers, companies, regulators, and governments.

Capitalizing the gains from minimizing electrical losses is essential for alleviating the current financial constraints in the sector. The region needs to invest more in infrastructure and in a better way in order to improve the quantity and quality of electrical services. In this sense, as this publication points out, it is essential to capitalize on the gains from minimizing electrical losses to alleviate the current financial limitations in the sector. This will increase the financial capacity of utility companies, facilitate future investments, and close financing gaps to meet infrastructure-related Sustainable Development Goals.

We hope that this knowledge product will help enhance the comprehension of the challenges associated with electricity losses in the region, as well as the policy interventions that can be employed to mitigate them, ultimately leading to the provision of efficient, affordable, and sustainable electricity services.

Ana María Ibáñez
Vice President of Sectors and Knowledge
Inter-American Development Bank

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List of authors

Rigoberto Ariel Yépez García, a Mexican citizen, is Economics Principal Advisor in Vice President for Sectors and Knowledge (VPS) of the Inter-American Development Bank. He holds a PhD in Economics from the University of Chicago.

Johanna Gomez Velasquez (Chapter 6), a Colombian citizen, is lead investment officer for Infrastructure & Energy at IDB Invest

Elizabeth Layton Herrera ((Chapter 6), a Colombian citizen, is an investment officer for Infrastructure & Energy at IDB Invest.

Raul Jimenez Mori, a Peruvian citizen, is a development effectiveness officer at IDB Invest. He holds a PhD in Economics from the University of Roma Tor Vergata.

Santiago López Cariboni (Chapter 9), a Uruguayan citizen, is a professor in the Department of Economics at the University of the Republic, Uruguay. He holds a PhD in Political Science from the University of Essex.

David Matías (Chapters 5 and 6), a Mexican citizen, is an economist at the Energy Division of the Inter-American Development Bank. He holds a Master's Degree in Economics from the College of Mexico.

Chapter 1

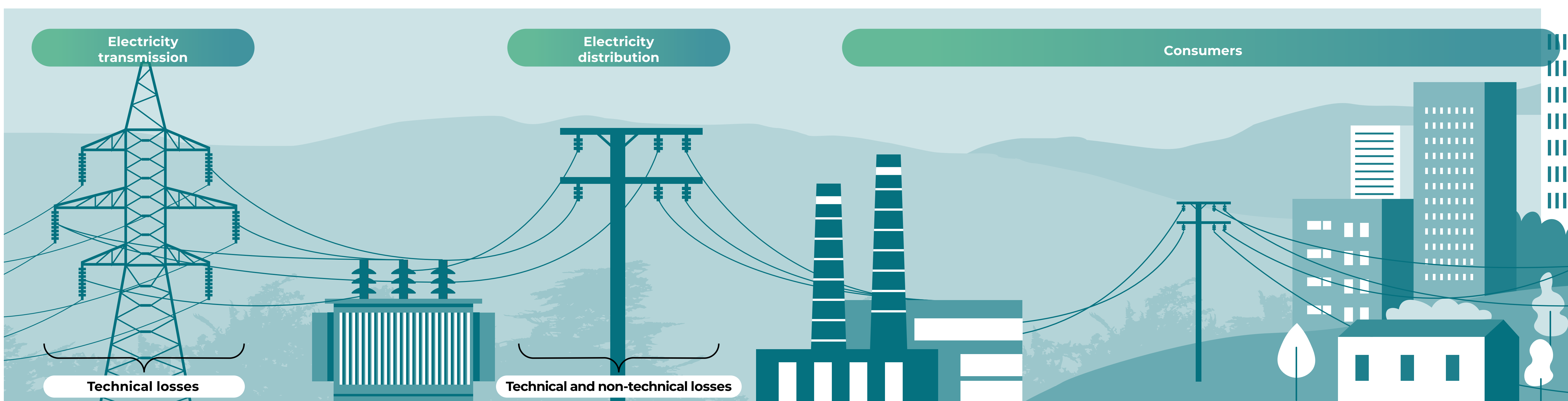
Executive summary: key findings and policy considerations

1.1 Introduction

Electricity losses in transmission and distribution constitute a central measure of the performance of the electricity markets. They are determined based on the difference between the energy generated and the amount billed to end users. Losses in the electricity transport system can be of a technical or non-technical nature and reflect the operational and institutional efficiency of electric power systems. Although a certain level of loss is natural, high levels indicate chronic investment deficits or problems in the functioning and operation of the system.

The underlying causes of high levels of electricity loss result from complex interactions between technical, financial, socioeconomic, regulatory, and political factors. In many cases, these factors go beyond the scope of corrective measures that electric utility companies can implement and can significantly impact the operation of energy markets.

High loss levels inevitably weaken electric utility companies' financial viability and can have fiscal and systemic consequences. They can undermine the ability to maintain and expand adequate infrastructure, thus negatively affecting the quality of electrical services. Quality deficiencies can impact the economy's competitiveness and, in particular, reduce the reliability of energy supply for the most vulnerable groups. Because this energy is unbilled, this situation can lead to overconsumption of electricity, which increases greenhouse gas emissions. Generating additional energy to offset these inefficiencies may require incremental investment, further widening the infrastructure gap in the region and increasing service provision costs.



From both economic and environmental points of view, reducing and controlling electrical losses is essential to achieve sustainable electricity markets. Given the complexity of the problem regarding losses, as well the negative external effects thereof, interventions aimed at reducing this problem involve multiple Sustainable Development Goals (SDGs) and are necessary for a successful energy transition. Specifically, to the extent that access to quality basic services is facilitated for vulnerable groups and energy savings are promoted, the reduction of losses is consistent with SDG 1, "No Poverty," and SDG 7, "Affordable and clean energy." Because these interventions seek to improve and expand infrastructure, as well as increase the quality of services, they also contribute to SDG 9, "Industry, Innovation and Infrastructure." Furthermore, the investments implicit in these interventions and the expected improvements in electrical services would contribute to SDG 8, "Decent Work and Economic Growth."

This publication offers a comprehensive view of the problem of electricity losses in the LAC region and its corresponding policy implications. The main questions to be answered are: What is the magnitude of the problem? Which factors influence the level of electrical losses What mechanisms have been successfully implemented to reduce the electrical losses in transmission and distribution? What factors are relevant to the implementation and performance of these mechanisms? What have been the corresponding effects associated with the levels of electricity loss? To answer these questions, we analyze evidence at both the macroeconomic and microeconomic levels, which shows specific experiences on the most important challenges and the main avenues to overcome the problem of electricity losses in the region.

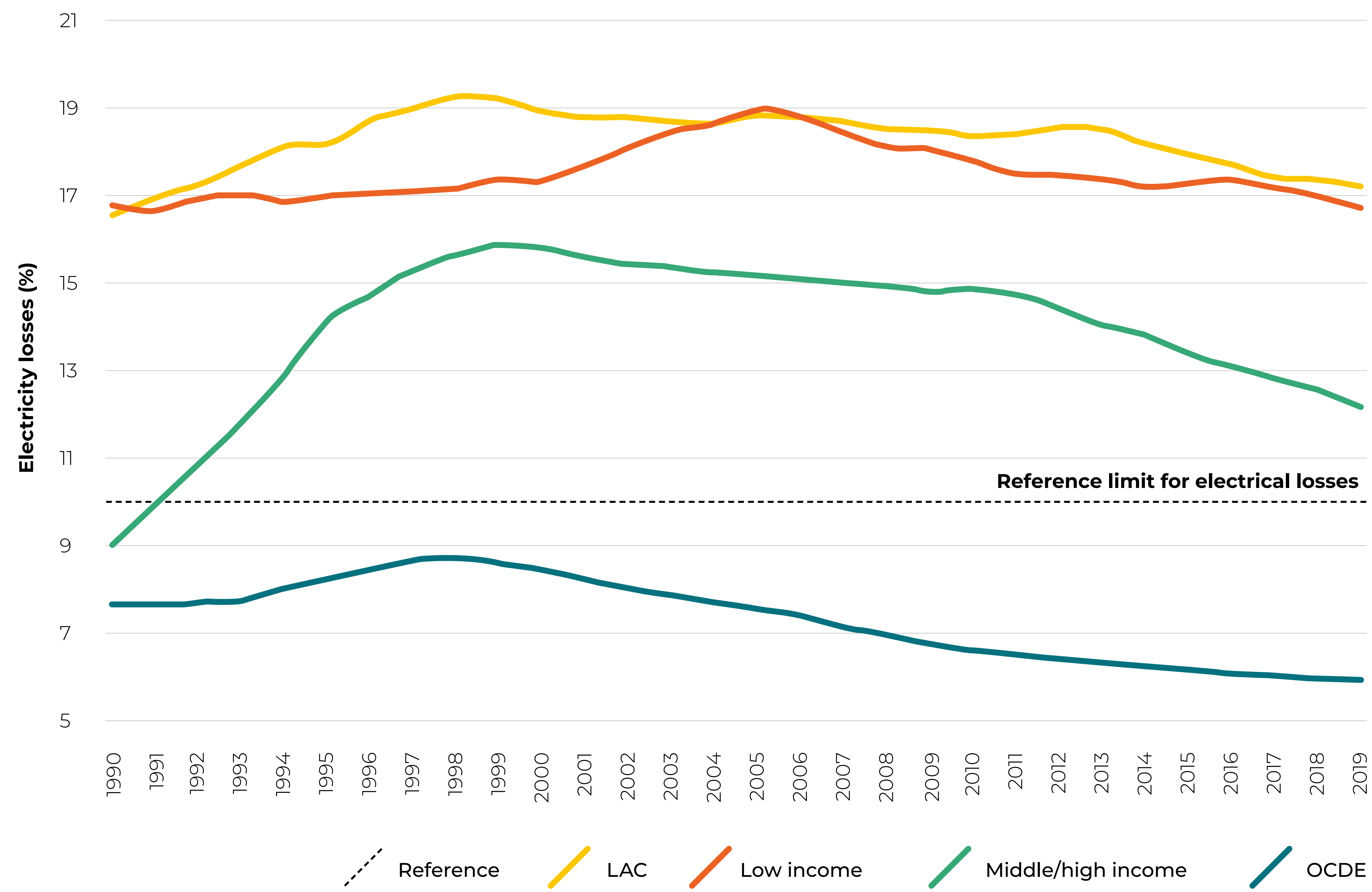
This volume continues a series of efforts by the Inter-American Development Bank Group to search for more efficient, equitable, and sustainable electricity markets. The contents draw on the Group's experience in supporting loss reduction programs and projects in the region in both the public and private spheres, as well as the associated learning agenda in the infrastructure sector. We hope this new product will strengthen the design and implementation of loss reduction policies.

1.2 Main findings

Finding #1. Electricity losses in Latin America and the Caribbean (LAC) represent an endemic and significant challenge for the region's electricity sector.

Over the past three decades, approximately 17% of the energy generated in the region has been lost (see Figure 1.1). These losses are three times higher than those of countries in the Organization for Economic Co-operation and Development (OECD) and are higher than any efficiency measure for a sustainable system. In absolute terms, in 2019, losses greater than the 10% limit were equivalent to 120 Terawatt-hours (TWh), exceeding the losses recorded globally in middle- and high-income countries. These losses were equivalent to the total energy generated in the region by solar and wind sources in the same year. The problem is widespread, as 22 of the 26 countries analyzed have levels above 10%, a figure that could be considered an acceptable limit. Even in countries with relatively low levels of losses, very divergent performance is observed among electric utility companies that serve different areas.

Figure 1.1 Evolution of electricity losses, 1990–2019

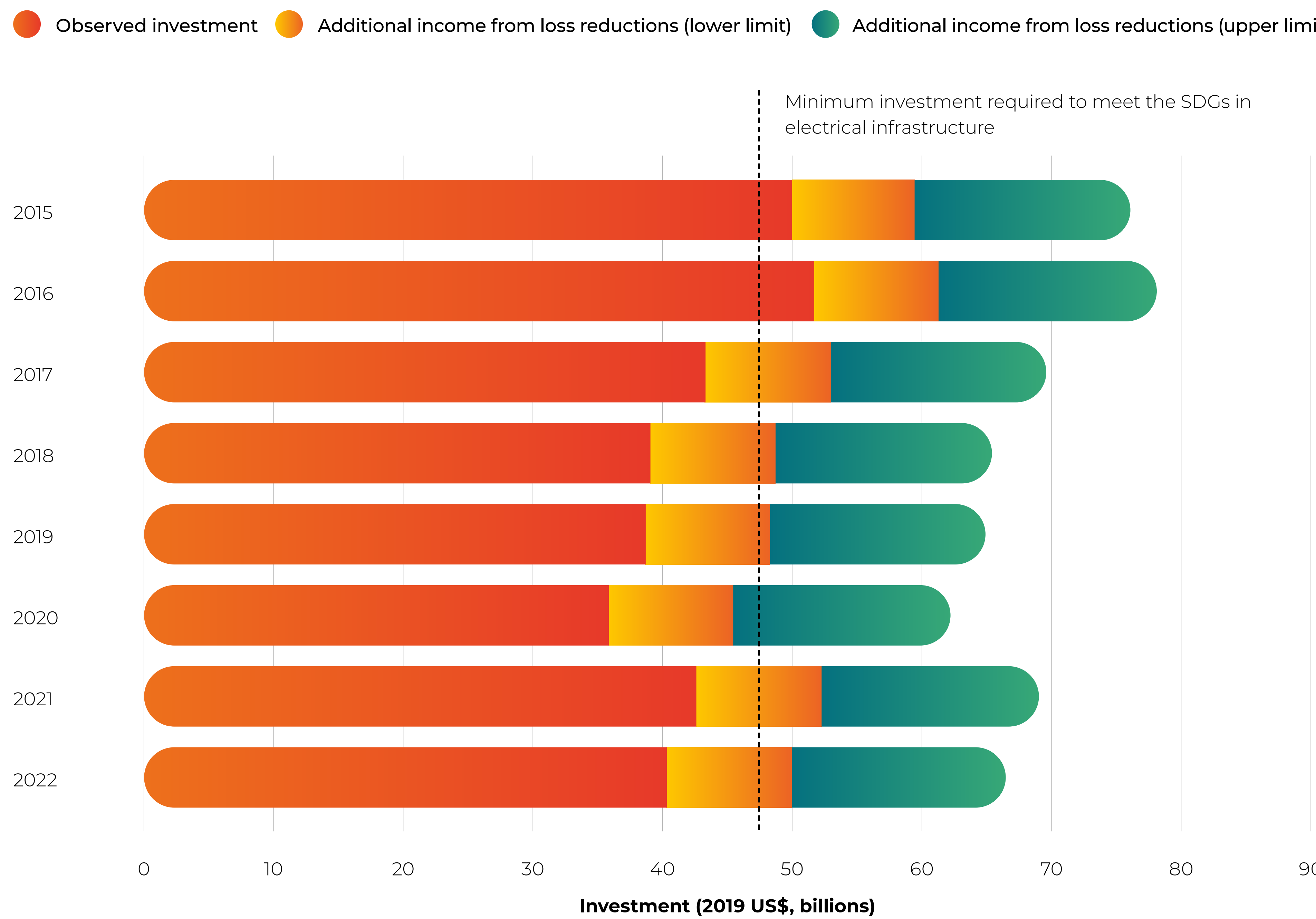


Source: Prepared by the authors based on data from the International Energy Agency.
Note: The figure shows the 5-year moving average of the percentage of losses. Low-income countries include low- and middle-income countries. The classification by income level follows World Bank's 2021 classification. Grouping of countries by income level excludes LAC and OECD countries.

Finding #2. The cost to distribution companies from electricity losses fluctuates between USD 9.6 and USD 16.6 billion annually, equivalent to 0.19% and 0.33% of the region's GDP, respectively.

To understand the opportunity cost of these resources, it is noted that their financial impact is comparable to the most far-reaching social programs in the region. For example, electricity losses in Brazil are more than two-thirds of the budget allocated to the "Bolsa Familia" program, while electricity losses in Mexico are comparable to the budget of the "Youth Building the Future" program. The financial performance of an electric power system directly depends on its ability to generate sufficient revenue to cover the costs of supplying electricity. Economic inefficiency and suboptimal resource management, resulting from the monetary cost of energy losses, pose an unsustainable situation for some countries. If not addressed, this problem impedes the ability to bridge the infrastructure gap. Considering that the region needs to invest at least USD 48 billion per year (0.8% of its GDP) to achieve universal access to electricity and advance the decarbonization of its energy mix over the next decade, recovering these lost resources could help close the infrastructure investment gap (see Figure 1.2).

Figure 1.2 Actual and required investments in the LAC electricity sector, 2015–2022



Source: Prepared by the authors based on IEA (2022), Cavallo, Powell and Serebrisky (2020), Brichetti et al., (2021), INFRALATAM database, World Bank PPI database and own estimates.

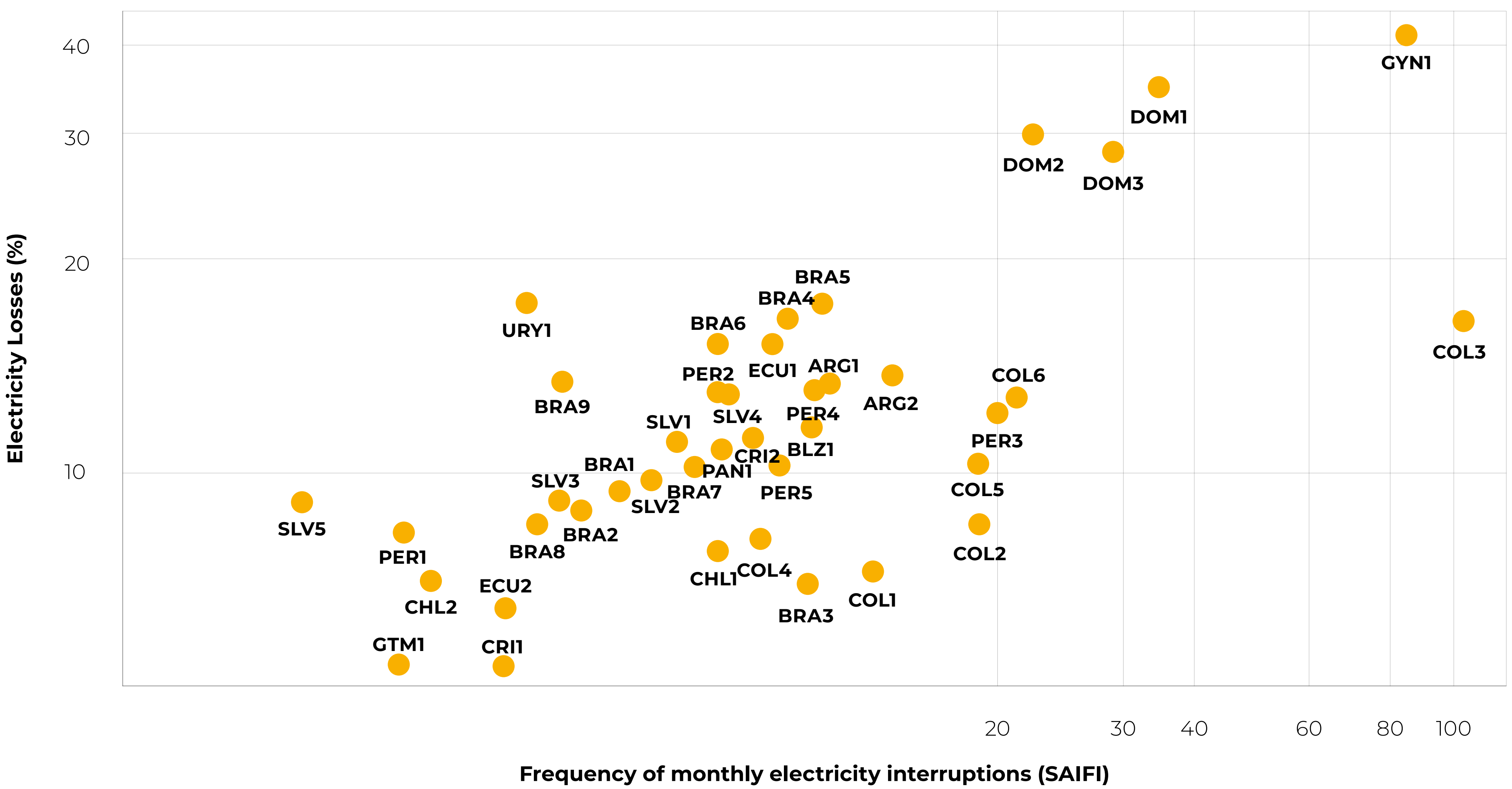
Finding #3. The environmental cost of electricity losses is substantial, stemming from technical inefficiencies as well as overconsumption due to unbilled energy.

The tolerance of energy losses is incompatible with energy transition because it discourages energy conservation and efficiency measures. These losses result in the generation of greenhouse gases (GHG) through two main mechanisms: on the one hand, through technical inefficiencies during energy transmission and distribution; on the other hand, through inefficient consumption by users, which in many cases is not adequately measured or billed. When technical inefficiencies cause losses, they tend to require the use of marginal installed capacity, usually with a larger carbon footprint, to compensate for excess energy demand. Electrical losses are estimated to cause between 5 and 6 million tons of CO2 annually, a volume of emissions that translates into a social cost of USD 320 million annually. In other words, these emissions are equivalent to the annual emissions of 1.3 million gasoline passenger vehicles, or 661 million gallons of gasoline consumed per year. This magnitude neutralized all GHG emissions that avoided using solar energy in 2019 in the region. Therefore, measures to control and reduce electrical losses are essential to the strategy against climate change.

Finding #4. Higher losses are associated with lower electrical service quality, mainly affecting the most vulnerable populations and their businesses.

High levels of losses are associated with lower levels of electrical supply reliability. Because they affect companies' financial sustainability and investment capacity, excessive losses negatively impact the distribution infrastructure's quality and services delivered (see Figure 1.3). This decrease in service quality may originate from a larger number of interruptions, which result in rationing programs that electric utility companies implement in order to preserve the integrity of the electric power system against excess demand or as a mitigation strategy to reduce financial losses. Furthermore, quality may be affected by the increased vulnerability to climatic events due to infrastructure investment deficiencies. Regardless of the mechanisms through which losses lead to a decrease in service quality, these have a greater effect on the most vulnerable populations, who live in areas with less infrastructure and have fewer resources to compensate for the deficiencies in the services received. Low-quality service represents a significant restriction on essential productive input, leading to systemic negative effects that weaken the economy's competitiveness.

Figure 1.3 Electricity losses and quality of service in Latin America



Source: Jiménez (2021).

Note: The figure includes 41 electricity distribution companies in 15 Latin American countries. Abbreviations: DOM: Dominican Republic, NIC: Nicaragua, GYN, Guyana, COL: Colombia, PER: Peru, ARG: Argentina, BRA: Brazil, ECU: Ecuador, CRI: Costa Rica, CHL: Chile, GTM: Guatemala, SLV: Salvador, PAN: Panama. The information corresponds to the year 2015 and was compiled from available public sources (web pages of public utility companies, regulators, ministries). Both axes are plotted on logarithmic scales. The y-axis, "Electricity Losses (%)," represents the portion of electricity that goes unbilled by the public utility company, resulting in direct financial losses. On the x-axis, SAIFI stands for "System Average Interrupt Frequency Index."

Finding #5. The persistently high electricity losses can be attributed, at least in part, to the hindrance of public services in politically sensitive environments.

It is crucial to underscore that the ongoing prevalence of significant losses within the electricity sector is indicative of intricate political and institutional difficulties, which in turn impede the proper operation of electricity markets. Tolerance for the persistence of losses may be associated with contexts of low income, high rates of informality, weak institutions, and the absence of progressive social policies. In other words, in situations where there is a need for more institutional coordination for the adequate provision of basic services and social protection instruments, losses as a form of informal transfer are more likely to be allowed or tolerated. This context can allow for political misuse since the problem tends to increase during electoral periods and economic crises. The recognition of these elements is fundamental to overcoming the problem of electricity losses.

Finding #6. Tolerance of electrical losses is ineffective in promoting equal access to quality electrical services.

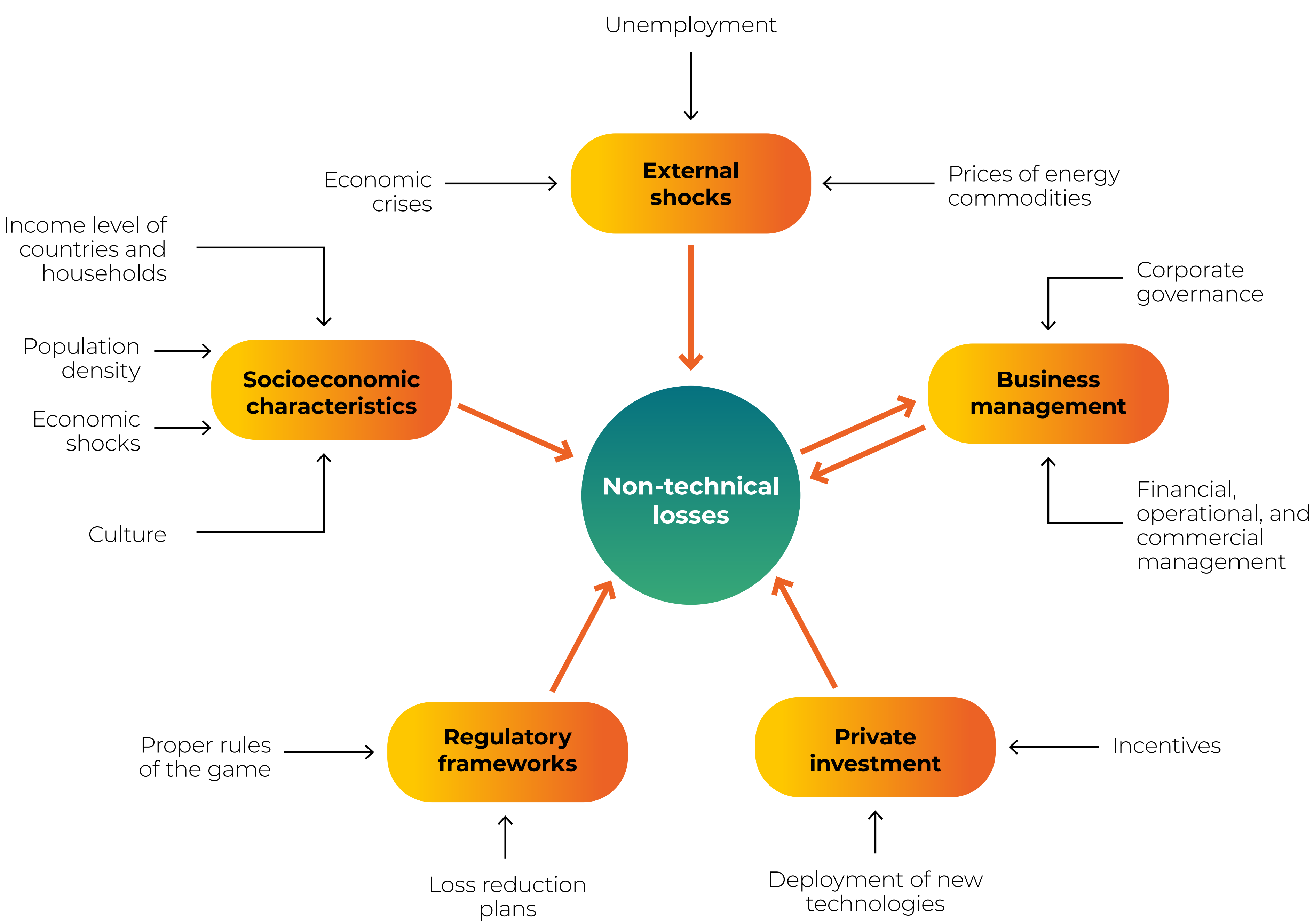
Permitting energy theft or its use as an informal subsidy mechanism represents a nontransparent and highly discretionary means of addressing society's energy needs. The persistence of losses has prevented the achievement of fundamental goals such as providing quality services and the financial and environmental sustainability of electric power systems. In effect, this type of practice generates an unequal impact on society because a portion of these losses is transferred to all users through higher electricity prices and lower quality of service. In summary, permitting electrical losses to offer electrical services to vulnerable groups is a costly and inefficient strategy. Alternatives like social tariffs have proven more effective in ensuring electricity affordability, particularly for vulnerable populations.

Finding #7. High levels of losses are also associated with other factors, including the socioeconomic characteristics of the population, economic shocks, company management, and institutional quality of electricity markets.

Similar to other measures of operational performance, losses are also the result of various factors within and outside the framework of action of electric utility companies (see Figure 1.4), largely via income shocks that affect users' ability to pay electricity bills. Losses are closely linked to the economic cycle; that is, they tend to increase in periods of high unemployment and low income. Problems with electrical losses are more persistent in low-income areas, although there are exceptions in which high-income areas also experience significant electrical losses.

Another related aspect is the precarious infrastructure and irregular electrical connections commonly found in urban settlements, where issues such as the absence of property titles can hinder the regularization of these connections. Similarly, weak institutional frameworks can affect the performance of the electricity market, especially when pricing mechanisms are not transparent or do not follow predetermined rules for cost recovery. This type of poor institutional framework can negatively impact the management of electric utility companies and act as a disincentive for their operational and commercial efficiency objectives.

Figure 1.4 Determinants of electricity loss levels



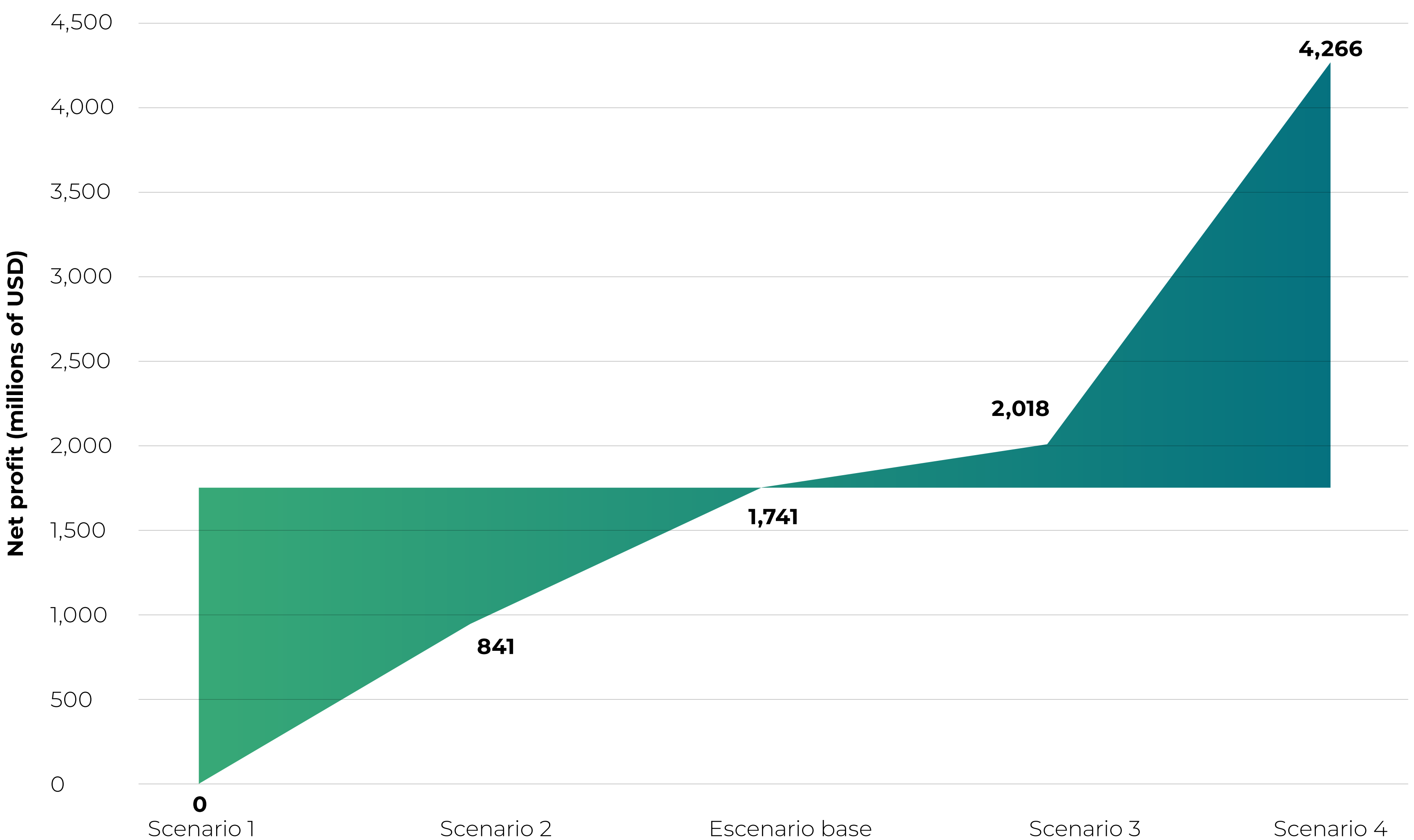
Source: Prepared by the authors.

Finding #8. An effective loss reduction policy would provide substantial net profits for all stakeholders in the electricity market.

Implementing a regional strategy aimed at reducing losses to 10% over a two-decade time horizon would be around USD 8.5 billion, with an economic rate of return of 18% (see Figure 1.5). This plan would yield approximately $1.7 billion in present-value economic benefits (using 2021 prices). It would also recover 1900 TWh of energy and prevent the emission of 113,000 kilotons of CO2. However, the cost of inaction is significant. Without policies to reduce electricity losses, it is estimated that 8000 TWh will be lost over the next two decades, with 3300 TWh representing losses exceeding 10%.

However, adverse conditions such as high financing costs, inadequate terms, and the implementing company's ability to monetize this policy may negatively affect its net socioeconomic benefit. Factors such as the alignment of incentives, economic and political crises, and political and social stability may also threaten the sustainability and effectiveness of these policies. In the following section, we discuss some policy considerations that may be relevant for improving the effectiveness of policies to reduce and control electricity losses..

Figure 1.5 Net benefits of the loss reduction policy



Source: Prepared by the authors.
Note: The different scenarios represented take into consideration variations in electricity demand and the effectiveness of the policy. Scenario 1 is based on target losses of 12.5%; Scenario 2 considers losses of 11%; the baseline case seeks a goal of 10% losses; Scenario 3 reflects a 10% increase in energy demand using the goals of the baseline scenario; and Scenario 4 seeks to reduce losses to 7%. It should be noted that all scenarios are discounted at a rate of 12%, but if a rate of 5% were applied, the profit would be greater.

1.3 Policy considerations

Reducing and controlling the problem of electricity losses is not simply investing in infrastructure but also understanding its multiple causes. This knowledge is essential for designing effective strategies. Although it is not possible to identify a set of actions that can be generalized to all contexts, we can discern certain elements that can help identify areas of intervention for the design of effective policies. Some of these elements are highlighted below: they are complementary and interrelated, and their joint implementation can generate significant synergy.

Policy consideration #1: There are no universal policies for reducing losses; instead, these measures address the conditions of each context.

The region is heterogeneous and presents different realities, complicating the implementation of universal loss reduction policies. The experiences reviewed suggest that loss reduction programs do not follow a single formula but are rather conditioned by various institutional frameworks, the financial restrictions of electric utility companies, and varied operational circumstances specific to each country.

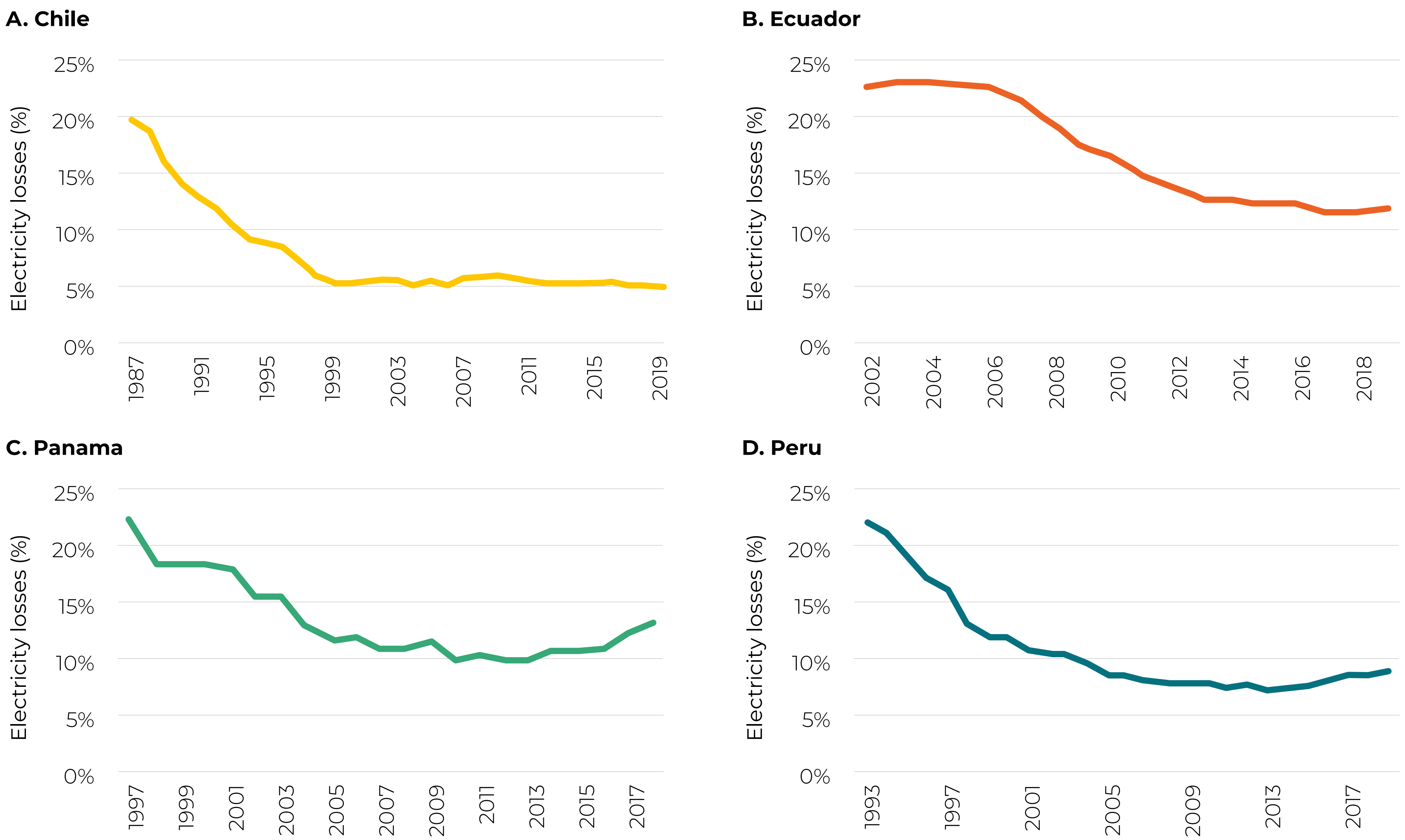
This means that to be effective; loss reduction policies need to start from a deep understanding of their causes and typology and seek measures with feasible goals that address social, economic, and political realities. Moreover, understanding the composition and characteristics of users affected by the loss reduction policy is essential when outlining its potential benefits. Likewise, it is essential to establish realistic goals and plans with adequate deadlines, considering factors such as investment capacity, available financing, and the economic environment. Although assessing the situation can be a complex and lengthy task, it should be considered the first step towards building consensus and recognizing the underlying factors that explain the problem of electrical losses..

Policy consideration #2: Loss reduction goals need to be deployed over the long term and require political support.

Ensuring political commitment to appropriate goals plays a central role in achieving intertemporal consistency in the measures required. For example, this can be achieved through the adaptation and enforcement of regulatory frameworks, as well as securing necessary investments from beneficiaries of political stability at higher levels. The population will also perceive such consistency in political support once they have facilitated the deployment of actions by the implementers of the loss reduction programs. Political support can also be operational by establishing transparency and accountability mechanisms in terms of effective support by different government areas and the achievement of goals by implementers.

Moreover, this political will needs to be sustained and consistent over time. The successful initiatives we reviewed share a common element: they have been implemented over long periods and have transcended several government cycles (see, for example, Figure 1.6). This makes it possible to establish a culture of responsibility for paying for the service over the years, discouraging the perception of free access to public services as a political strategy. Additionally, implementing long-term programs provides an opportunity to continually observe, learn, and improve these programs as they develop. Similarly, political consistency requires independent, strong, and transparent supervisory bodies and companies that operate in an electric power system..

Figure 1.6 Loss trends in the distribution sector in countries that have implemented reduction measures



Source: Prepared by the authors based on information collected by the IDB Infrastructure Department.

Note: Graph A presents the losses disclosed by Enel in its annual reports. Graph B shows the figures for distribution losses in Ecuador, taking as reference the annual reports of ARCERNNR. Graph C shows the distribution losses reported by the National Public Services Authority (ASEP) of Panama in its annual reports. Finally, Graph D illustrates the distribution losses reported by Osinergmin in its annual reports.

Policy consideration #3: Regularizing electricity services to improve their quality has become a pressing social demand, with a noticeable willingness to pay for these enhanced services.

The goals of reducing and controlling losses and improving the quality of electrical services are complementary and can be effectively integrated. Significant improvements in service quality could encourage the acceptance of loss-reduction programs. A high-quality electrical service creates incentives for users to be willing to pay higher rates or admit the regularization of the service. The evidence indicates that users would consider a higher electricity price acceptable if there were guarantees of notable improvement in the quality of service. Therefore, including losses in rate schemes must go hand in hand with strategies aimed at increasing the quality of service. A strategy that prioritizes improving service quality, such as reducing losses, could result in a cost-efficient solution with a significant impact on the electricity sector.

Policy consideration #4: Regulatory frameworks play a central role in establishing incentives that lead to and encourage the implementation of loss reduction and control measures.

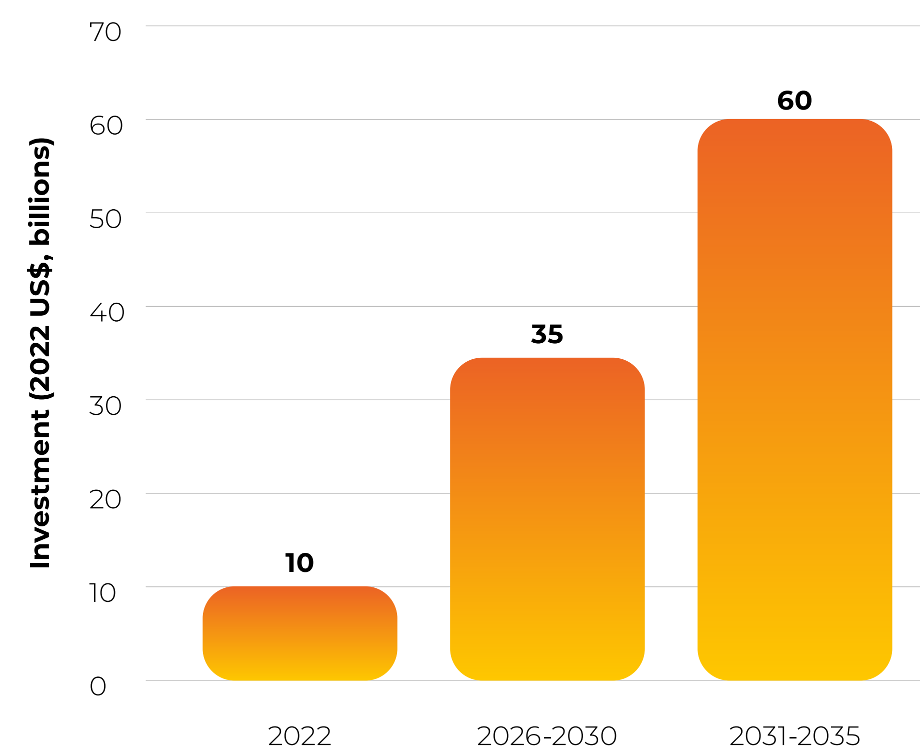
An essential element of loss reduction and control strategies is a transparent regulatory framework that stays consistent over time and incentivizes utilities to implement these programs. This regulatory framework can provide electric utility companies with spaces for action, guaranteeing their autonomy and independence so that they prioritize their business and assume responsibility for the consequences (for example, not achieving loss reduction goals) with clear accountability. Regulatory frameworks can also establish transparent and predetermined mechanisms for remuneration proportional to the capital allocated to companies with better efficiency indicators. In this sense, aligning incentives is crucial for companies to achieve and maintain long-term loss-reduction goals. Therefore, it is fundamental to establish pricing mechanisms that allow for the recovery of costs and to have a rating system based on the performance of electric utility companies. Of course, the objectives set for utility companies must be in line with their capabilities and be supported by appropriate execution mechanisms.

Simultaneously, the regulatory frameworks of the electricity sector need to be aligned with and supported by the corresponding legal frameworks. For example, undertaking measures that impose sanctions to curb energy theft, including enacting legislation that imposes penalties for non-payment or the unauthorized utilization of public services..

Policy consideration #5: Investment in infrastructure is an urgent priority for reducing electricity losses in the region.

It is evident that there is an investment gap in electrical infrastructure, a situation that hinders the modernization of the electric power system and perpetuates its inefficiencies and quality deficiencies. It is estimated that investment in electricity networks and storage should be multiplied by three to six times to achieve zero-emissions goals (see Figure 1.7). The investment necessary to address the problem of losses alone is substantial, in the order of USD 8–9 billion. However, making such investments to control losses in the electric power system is profitable from both socioeconomic and environmental points of view and indispensable from a financial point of view. These investments can be considered in modernization plans for a more resilient electric power system.

Figure 1.7 Investment in electricity grids and storage systems in LAC in the context of the net zero emissions scenario



Source: Prepared by the authors with IEA data (2023).
Note: The 2050 Net Zero Emissions Scenario (NZE) is a scenario proposed by the International Energy Agency that illustrates the actions required for the global energy sector to achieve net zero CO2 emissions by 2050. This scenario also aims to minimize methane emissions from the energy sector and establishes concrete actions for the United Nations Sustainable Development Goals related to energy.

Financing conditions are important for facilitating investments to reduce losses at the necessary pace. For example, financing costs must be consistent with the income obtained from the energy recovered by the program, and the terms must be sufficiently long and have grace periods that correspond to the times in which such recovery is expected to occur. Furthermore, it is crucial to stress that reducing energy losses can postpone the need for investments in generation capacity, alleviating the pressure on new investments to meet excessive energy demand.

Policy Consideration #6: Private participation plays a fundamental role in transitioning to more efficient electric power systems.

Given the region's historical underinvestment and limited fiscal capacity, private participation is a cornerstone in funding the investment required to reduce and control the levels of electricity losses in the region. Private participation is central in attracting and using investments to modernize electric power systems and sustain multi-year investment plans to control electrical losses. Estimates show that the private sector will have to provide nearly 73% of the capital required in a zero-emission scenario by 2050. It is important to stress that these multi-year investment processes require the presence of stakeholders with financial strength and liquidity in the energy markets since such processes imply substantial commitments to investments over long periods.

Policy Consideration #7: An evaluation and monitoring system to track the effectiveness and efficiency of loss reduction strategies is an essential part of long-term programs.

Such evaluation and monitoring systems help identify weaknesses in the design and implementation of loss reduction measures. The persistence of electricity losses in the region is mainly due to intersectoral and institutional complexities, which makes it challenging to implement effective measures. Therefore, it is crucial to establish a unit to coordinate different loss-reduction programs. This unit should be responsible for evaluating and monitoring the results of any strategies implemented to reduce electrical losses to improve these strategies based on the results obtained continually.

Policy Consideration #8: Digitalisation of the electricity sector is strategic for loss-reduction initiatives.

Digitalisation is changing the electrical distribution sector, allowing energy management optimization and greater precision when measuring consumption. Advanced technological tools, such as AMI meters, smart substations, sensors, and digital control systems, facilitate the real-time collection and management of electricity consumption data. By enabling detailed analysis and detection of anomalies, these technologies help identify areas of intervention to manage losses and improve the system's efficiency as a whole.

The modernization of infrastructure, in turn, needs to be complemented with information analysis, management software, and platforms. A clear example is the "Energizados" project, which applies machine learning techniques to detect consumption anomalies. This approach has proven more effective than conventional approaches in identifying illegal network connections. Technological advances can also be adapted to the needs of specific populations, as is the case with the growing penetration of prepaid meters, which allow for the deployment of pay-as-you-go models that manage the consumption capacity of households cost-effectively for electric utility companies (see, for example, Figure 1.8).

Regulatory frameworks and roadmaps can drive the digital transformation of the electricity sector while mitigating the risks associated with investments in the sector. At the same time, private investment plays a critical role in meeting the magnitude of the investments necessary for the modernization of the energy sector, especially in areas with limited public resources.

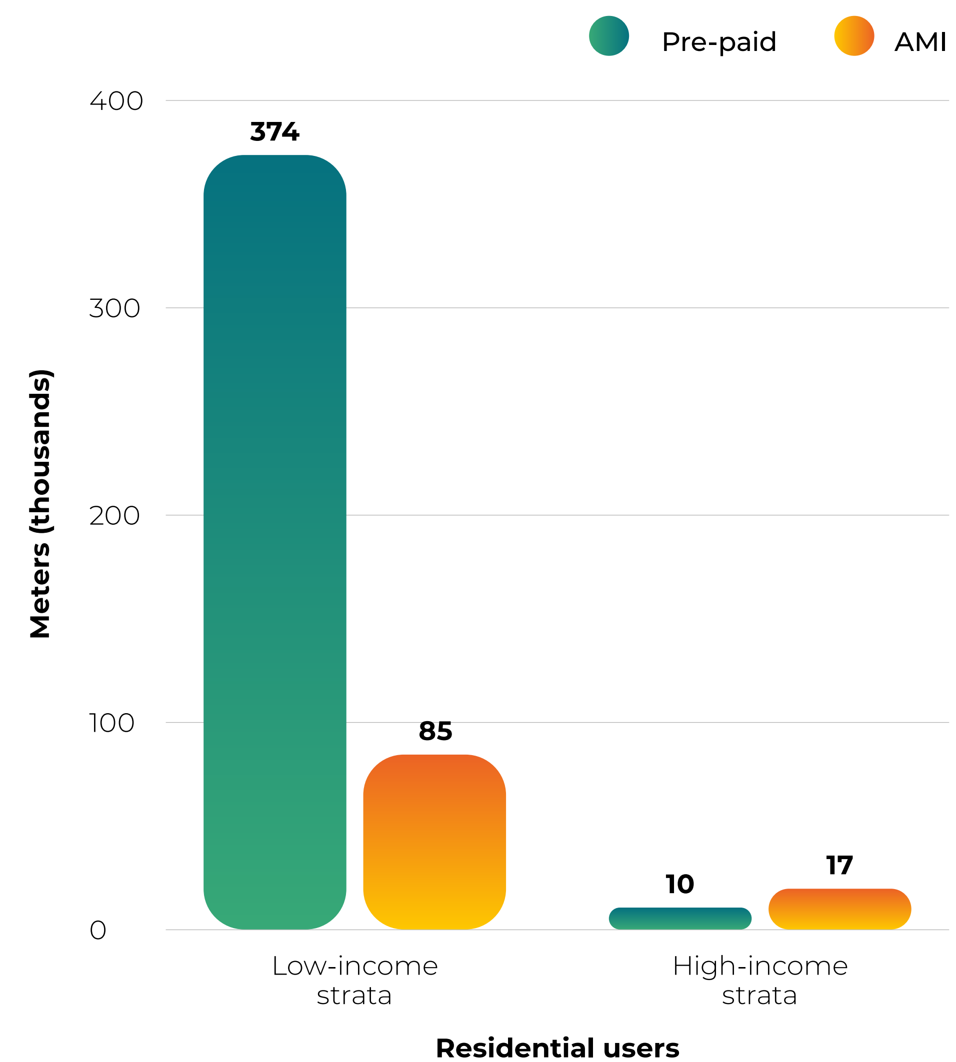
Policy Consideration #9: Loss reduction policies would benefit from incorporating countercyclical considerations.

Experience accumulated after various external shocks, including economic crises, has shown that these can exacerbate the problem of electrical losses in Latin America and the Caribbean. This relationship is manifested through a decrease in user payment capacity and an increase in electricity prices, which leads to greater incentives to avoid paying for electricity. Loss-reduction strategies must, therefore, consider economic contraction scenarios, where it is likely that losses will tend to increase. Anticipating these events through the proactive design of contingency plans will help mitigate their effects. Therefore, it is necessary to establish protection mechanisms for the most vulnerable consumers, such as subsidized rates or temporary subsidies, to prevent late payments and guarantee equitable and sustainable access to electrical services.

Policy Consideration #10. Loss-reduction policies can be part of national strategies against climate change.

Loss reduction and control measures are compatible with climate change mitigation and adaptation strategies. Given the significant carbon footprint of electrical losses, any measures taken to reduce and control them constitute climate-change mitigation actions. Any avoided emissions can be included in the Nationally Determined Contributions (NDC). Likewise, given that loss reduction policies typically involve improving electrical networks, they can also include investments in adaptation to improve the service provision's resilience. Adaptation measures against natural events of greater frequency and severity, such as heat waves, storms, hurricanes, and other catastrophic events, seek to preserve the continuity of service and reduce infrastructure vulnerability while achieving higher levels of operating efficiency. .

Figure 1.8 Distribution of AMI and prepaid meters by sector in Colombia, 2021



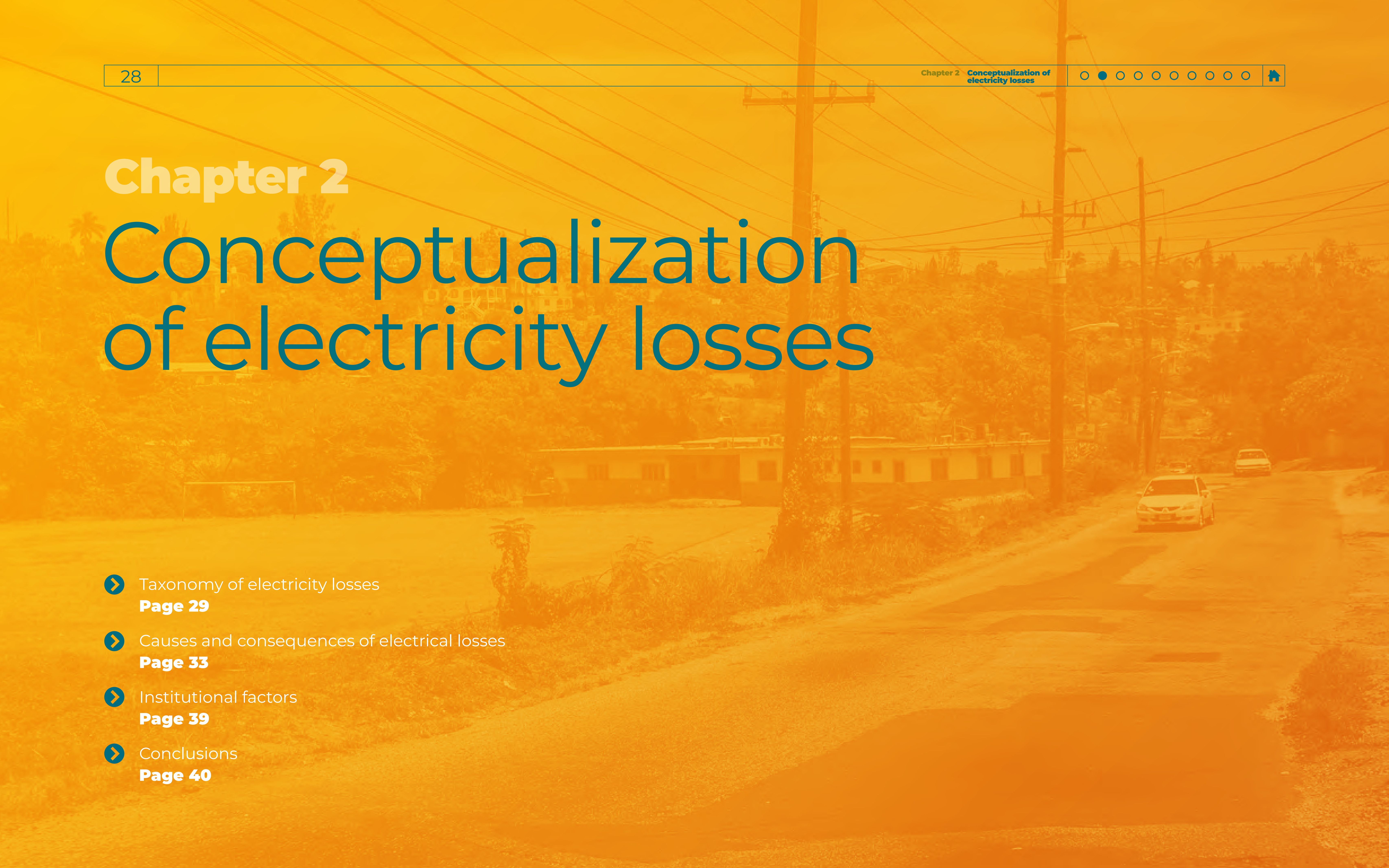
Source: Prepared by the authors with data from the Superintendency of Residential Public Services (2022).
Note: The low-income strata include strata 1, 2 and 3, while the high-income strata include strata 4, 5 and 6.

Policy Consideration #11: Effective mitigation strategies for losses require a comprehensive approach encompassing design and implementation aspects, inter-sectorial collaboration, and social awareness initiatives.

The design of loss reduction programs must address aspects beyond those related only to the technical deployment of infrastructure. For example, it is important to consider elements such as the status of users' property titles, their economic situation, the suitability of the properties, and the appropriate geographic areas to make connections, among other relevant aspects. This requires intersectoral coordination between participants in the electricity sector and ministries whose collaboration can be streamlined by identifying focal points and political support. Communication with the target population is also a determining factor in facilitating the acceptance of these policies. Such communication should highlight the economic, environmental, financial, and sectoral benefits of implementing these policies. Effective communication of these benefits to end users and key stakeholders in both the government and the electric power system can reinforce consensus and political-social support for these programs.

Policy Consideration #12. Best management practices in electric utility companies are key to loss reduction strategies.

An appropriate institutional framework characterized by providing autonomy and establishing suitable incentives must be accompanied by exceptional corporate governance practices, thereby facilitating corporations' utilization of these incentives. The policies and practices that guide the activities of the electric utility company constitute the counterpart of the regulatory framework. They can play a key role in the assimilation and implementation of loss reduction policies. For example, these governance frameworks may include performance monitoring practices essential for ensuring operational sustainability.



Chapter 2

Conceptualization of electricity losses

It is crucial to accurately define a problem before devising appropriate measures to address it. This chapter offers a conceptual framework for comprehending the energy losses in electric power systems. It begins by delineating the definitions and broader classifications of the various types of losses, followed by a discussion of their primary causes and potential consequences. As we will explore, the issue of energy loss extends beyond the strictly technical aspects of electric power systems. The purpose of this conceptual map is to enhance our comprehension of the complexity of the problem and, to some extent, facilitate the development of foundational principles that offer a thorough perspective on electrical losses in subsequent chapters.

2.1 Taxonomy of electricity losses[1]

Energy losses occur throughout the electric power supply chain and represent a key measure of operational, commercial, and financial management efficiency. In general terms, losses are calculated as the difference between the electricity available for final consumption and the energy billed to end users. Electricity losses can be divided into technical and non-technical losses. For example, losses in electricity transmission are typically of a technical nature and represent a measure of the technical efficiency of the system, whereas losses related to non-technical factors reflect elements of the commercial efficiency of electric utility companies.

Definitions and monitoring of losses may vary across countries. Figure 2.1 shows a simplified diagram of the electric power system. Although the losses incurred during energy transformation were not discussed in this book, it is important to highlight the generation subsector. In the energy transformation stage, various types of fuels used for electricity generation were considered as inputs. When combined, losses during transformation[2] represent approximately two-thirds of the total input (IEA, 2012). The efficiency level varies depending on the plant size, age, and load factor. In addition, efficiency depends largely on the technologies that make up the electricity generation mix in each country. For example, losses in hydroelectric generation represent approximately one-eighth of the total input, whereas losses from combined-cycle gas-fired heat generation represent approximately 54%.

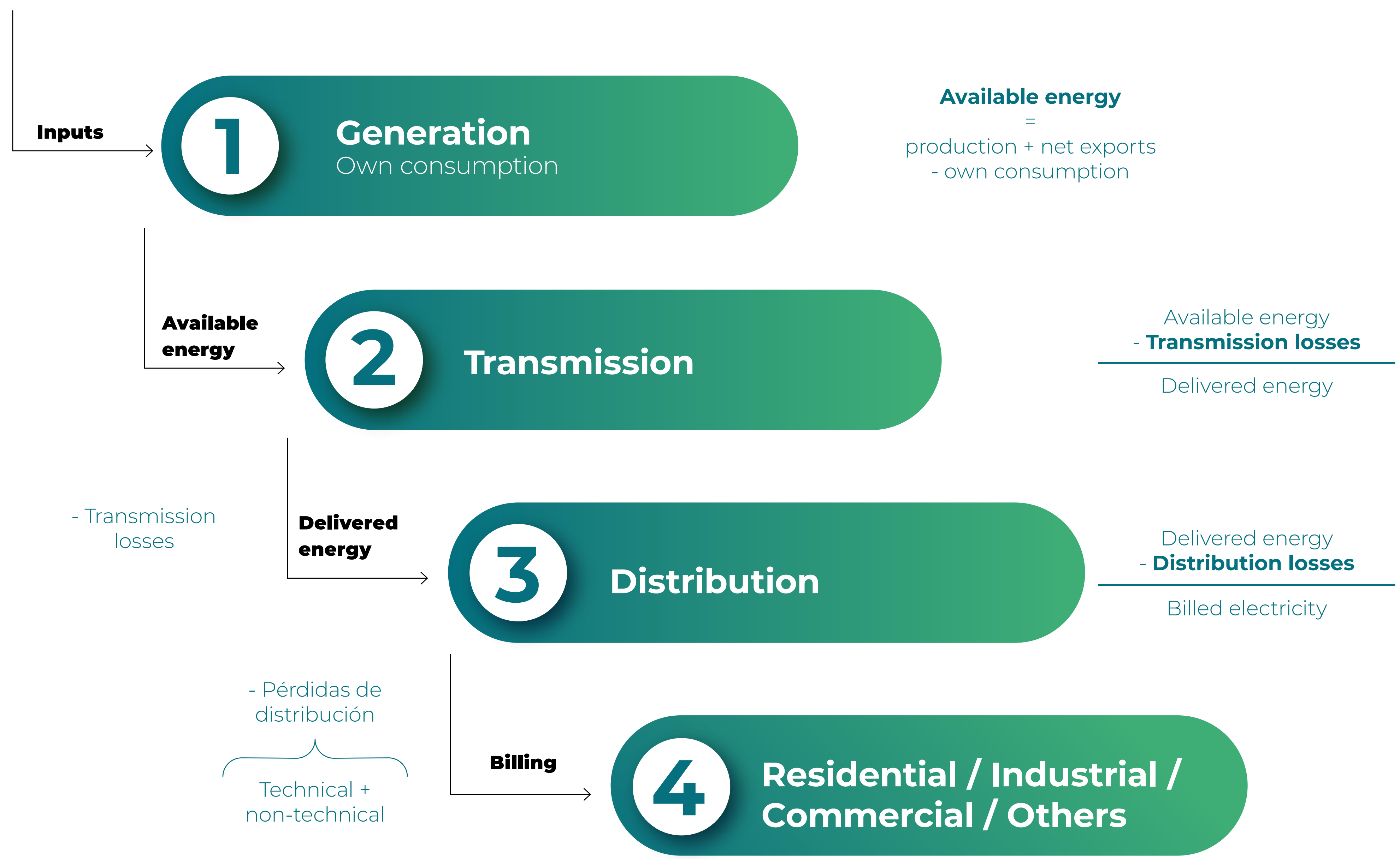
Once electricity is generated, it is transmitted via high- and medium-voltage grids (e.g., those with voltages exceeding 100 KV). The primary causes of electricity transmission losses are technical factors, weather events, and geographical conditions. In addition to technical factors, non-technical factors contribute to electricity distribution losses to end users. This is because, in addition to energy transport, distribution and/or commercialization involve various activities such as connection, metering, and charging for the service. A comprehensive categorization of the electricity losses is presented in the following section.

1. This section is based on Chapter 1 of the work by Jiménez *et al.* (2014).
2. This includes self-consumption of electricity, that is, the energy used for the operation and maintenance of power generation plants.

It is important to bear in mind that the measurement of losses in each subsector of the electric power system, namely generation, transmission, and distribution, in a totally differentiated manner is not always feasible. Even when transmission activities are delegated to specific companies with separate business units, the generation and/or distribution subsectors may be involved in electricity transmission. This is exemplified in Chile and Peru, where reports on electricity transmission encompass power lines owned by the generation and distribution subsectors. Nonetheless, the definition of transmission lines varies among countries, complicating the comparison of losses between systems that employ different definitions. For instance, in their transmission classification, Bolivia, Paraguay, and Nicaragua classified voltage lines below 110 KV, which are subject to higher technical losses than higher voltage lines.

Electricity losses during transmission are primarily attributed to technical factors, climatological events, and geographical conditions.

Figure 2.1 Losses in the flow of the electric power system



Source: Prepared by the authors.

Classification of electrical losses[3]

As previously stated, there are two general categories of losses in electric power systems: technical and non-technical.

Technical losses

Technical losses occur in the transmission and distribution lines, which can be divided into fixed and variable losses:

1. **Fixed technical losses:** These are losses caused by physical deficiencies such as hysteresis, losses that occur in the core of transformers, and losses that result from the corona effect in transmission lines. The corona effect in transmission lines is a phenomenon where the intense electric field ionizes the air around a conductor, creating a luminous halo and energy loss. It occurs in high voltage conductors and can reduce the efficiency of electrical transmission. Fixed technical losses are proportional to the voltage and are independent of the electricity flow.. Because the voltage varies relatively slightly with respect to its nominal value, these losses are treated as constants that depend mainly on the quality of the line. Although highly dependent on the context, this type of loss can range from 20% to 40% of all technical losses.

2. **Variable technical losses:** losses caused by the flow of current in grid lines, cables, and transformers. These losses are related to energy transmission and proportional to the resistance of the conductors and the electricity they carry.

Electricity meters are another source of electricity loss. Similar to any other component of a power supply system infrastructure, meters are subject to malfunctions and inefficiencies. For example, in Great Britain, these losses represent 3% of total technical losses (Ofgem, 2009).

These definitions have two important implications. First, because the main component of variable technical losses is the power flow, these losses depend on the load levels. These losses increase with load and vary seasonally; therefore, demand management plays an important role in their control. Second, both the distance from the point of generation and the demographics of the end market partially determine the losses and cost of supply. Thus, rural areas with low population densities are expected to register a higher loss level than urban areas.

Technical losses are negatively correlated with urbanization rates and population density.

3. See also Ofgem (2003, 2009) and Antmann (2009).

Efficiency

Technical losses are therefore inherent in the transmission of electricity, which is why they are closely related to the characteristics of the infrastructure of each energy system. Therefore, reductions in this type of loss are considered energy efficiency gains in transmission and distribution activities.[4] Although these efficiency gains are primarily linked to the quality of the energy transmission grid infrastructure, it should be noted that additional investments in digitalisation currently play a central role in achieving optimal efficiency levels.

Non-technical losses

Non-technical losses correspond to electricity delivered to but not paid for by users, a situation that translates directly into financial losses for the energy provider. This type of loss is caused by factors external to the electric power systems and is related to the management carried out by the energy companies. Depending on the type of source, these losses can be attributed to:

1. **Theft:** This is the energy unlawfully appropriated by users through informal connections to the network.
2. **Fraud:** Fraud arises from modifications to the measurement equipment made by the users, or in collusion with the operators, in order to register lower levels of electrical consumption than actually consumed.
3. **Unmetered electricity** mainly due to inadequate metering or lack of metering. In some cases, it may even include electricity used for street lighting and traffic signals (Ofgem, 2009). In the region, there are cases in which electricity service is provided to low-income areas or informal settlements without measurement of consumption at the household level.[5]
4. **Management problems:** These originate, for example, from accounting errors and poor maintenance of customer records.

From the perspective of an electric utility company, non-technical losses are often referred to as commercial losses because the proper metering and billing of electricity is an integral part of business management (Antmann, 2009). It should also be noted that the sources of the losses mentioned above show a certain degree of impossibility for companies to measure the electricity supplied to end users. That is, companies lose revenue from electrical consumption that they cannot attribute or identify. However, there are cases in which non-payment (electricity billed but not paid for) is also recorded as a loss. This means that, although the consumption is measured and invoiced correctly, it can be considered as a loss due to the low collection capacity of the company.

4. See Bentancur et al. (2010) for a detailed analysis of the experience of the National Administration of Electric Power Plants and Transmissions of Uruguay in improving the voltage levels of distribution lines.
5. In contrast, countries such as Mexico and Costa Rica have tariff schemes that include minimum charges under which the equivalent of 25 to 30 kilowatts/hour is billed, even if household consumption is zero. Given that under this scheme charges can be generated for electricity not supplied, this represents the opposite case to that of non-technical losses.

Loss levels: In view of the above, the expected level of electrical losses in transmission and distribution systems will depend on interrelated factors within the structure of the system (power line voltage, loads, climate, density of the service area, and so on). The levels observed in high-income developed countries are usually used as a reference, where losses are mostly technical and where there are adequate infrastructure and monitoring systems that allow them to be minimized. However, even in these countries, losses can fluctuate considerably. For example, over the past four decades, the average losses in high-income OECD countries have fluctuated between 8% and 6% (see Chapter 4). In line with this, the US Energy Information Administration (EIA) estimates that losses averaged approximately 5% between 2017 and 2021. The abovementioned levels provide an indicative range (5–8%) of electrical losses that could be expected from a relatively healthy operation. The following section discusses factors that could explain these levels and/or deviations.

2.2 Causes and consequences of electrical losses

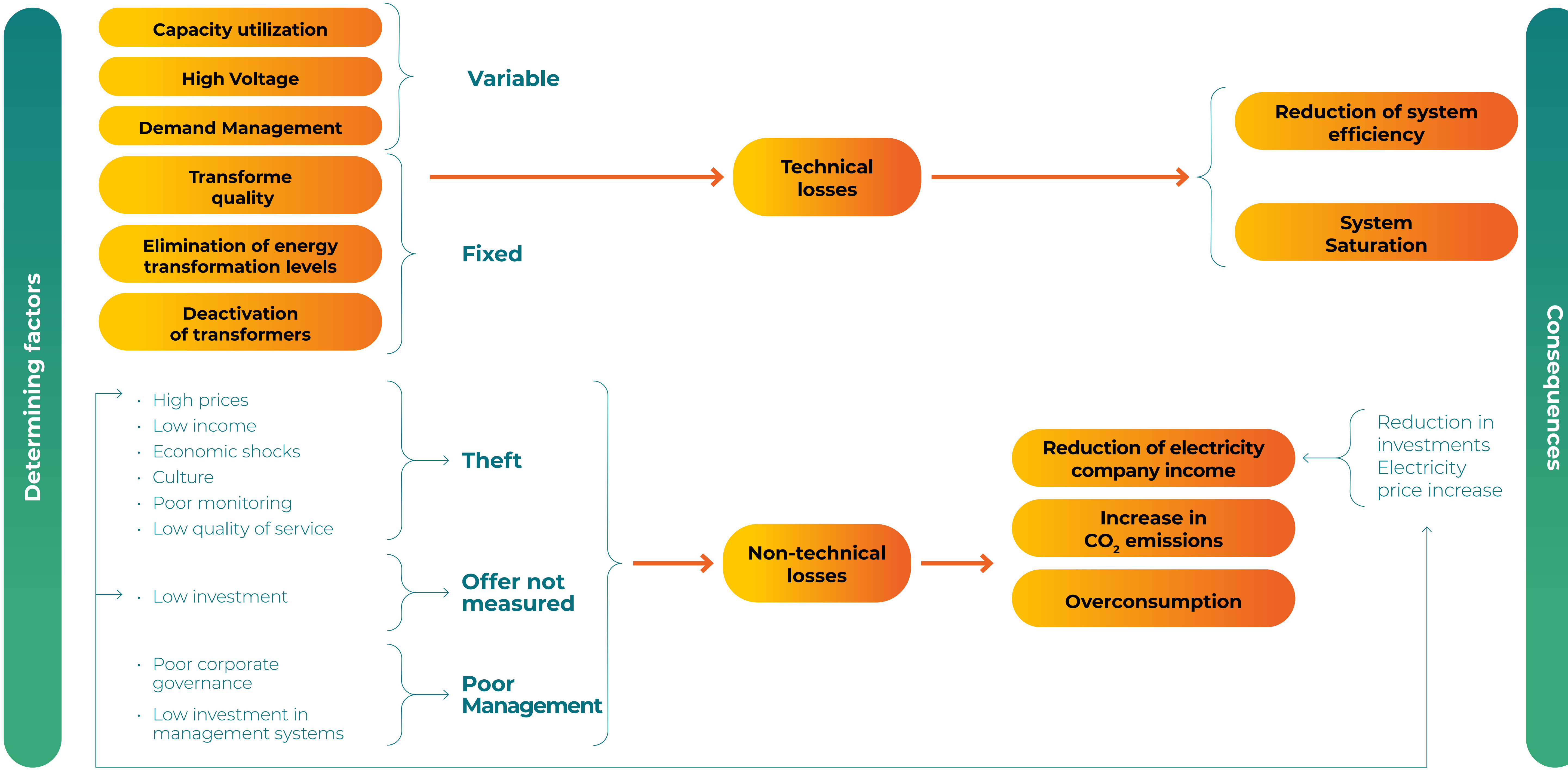
This section presents the logic chain between the causes and consequences of electricity losses. Figure 2.2 illustrates a classification of the potential causes and effects of the two types of electrical losses. Although the model described is direct and straightforward, experience has shown that two problems occur in practice when diagnosing electrical losses: it is not easy to identify the source of the losses nor to measure their relative contribution to the magnitude of the problem. Such limitations make it challenging to design effective measures to mitigate this problem.

Three important factors can also be inferred from Figure 2.2:

1. The listed determining factors are closely linked; therefore.
2. Reduction measures require a comprehensive approach that addresses the different causes in a cross-cutting manner.
3. High levels of losses can lead to counterproductive cycles that increase the cost of electrical services and reduce investment.

Over the past three decades, the average rate of losses in high-income OECD countries has fluctuated between 8% and 6%.

Figure 2.2 Causes and consequences of electricity losses



Source: Prepared by the authors.

Causes of technical losses

Except for demand management and in line with what has been described in the previous section, a relevant part of the factors that explain technical losses is closely related to the physical infrastructure of the electric power system. This, in turn, represents a restriction on the levels of efficiency that the system can achieve. In other words, even when optimal demand management strategies are applied, the capacity to deal with demand and load peaks is limited by the generation capacity, as well as by the capacity of the transmission and distribution lines. Therefore, it is important to direct the attention and investment to the factors that generate comprehensive improvements in the infrastructure of the system.

Causes of non-technical losses

As previously mentioned, the primary sources of non-technical losses are theft, fraud, unmetered consumption, and management problems (consumption that is measured but not billed). These factors are related to each other but differ in nature. Theft can arise from a combination of rising prices and low user incomes. The affordability of electricity services can be permanent or temporary due to economic crises; therefore, an analysis of macroeconomic factors is relevant.

However, a latent perception in some systems is that theft can also occur because of cultural factors. This is the case for customer segments that are not used to paying for public services. Practices that lead to providing these services free of charge contribute to creating such situations. To the extent that these practices persist over time, they generate a habit and perception that these services should be "free," all of which create a problem of financial sustainability for companies in the sector.

Irregular connections and/or meter tampering may arise as a response to poor-quality services or difficulties in exercising control faced by public service providers. The perception of quality and the corresponding customer satisfaction is a growing concern in electricity markets. It is challenging to control energy theft and expect user acceptance when the service quality is low. From the perspective of the end user, the fact that the services are of low quality can discourage the signing and fulfillment of contracts with electric utility companies. Therefore, those who do not reach minimum levels of service quality find themselves in a position of scarce political capital or little institutional credibility to carry out corrective actions. However, energy theft control plans can be intensified in zones or service areas with severe social and security problems.

The lack of adequate infrastructure for measuring and billing user consumption also explains non-technical electrical losses and, owing to investment restrictions, constitutes a latent problem in the region. In the Dominican Republic and Brazil, for example, a significant percentage of irregular users whose connections have been made by household members and/or are part of networks that require improvement and modernization have been identified. To a certain extent, this situation is explained by the disorderly growth of Latin American cities, which would have exceeded the investment capacities of companies in the sector. This situation has led to the persistence of a deficient energy supply and large groups of users who do not pay for these services.

It is difficult to enforce control over energy theft and expect acceptance from users when the quality of the service is low.

Informality in access to electricity services is closely related to the existence of irregular settlements, which poses serious challenges for electric utility companies, namely:

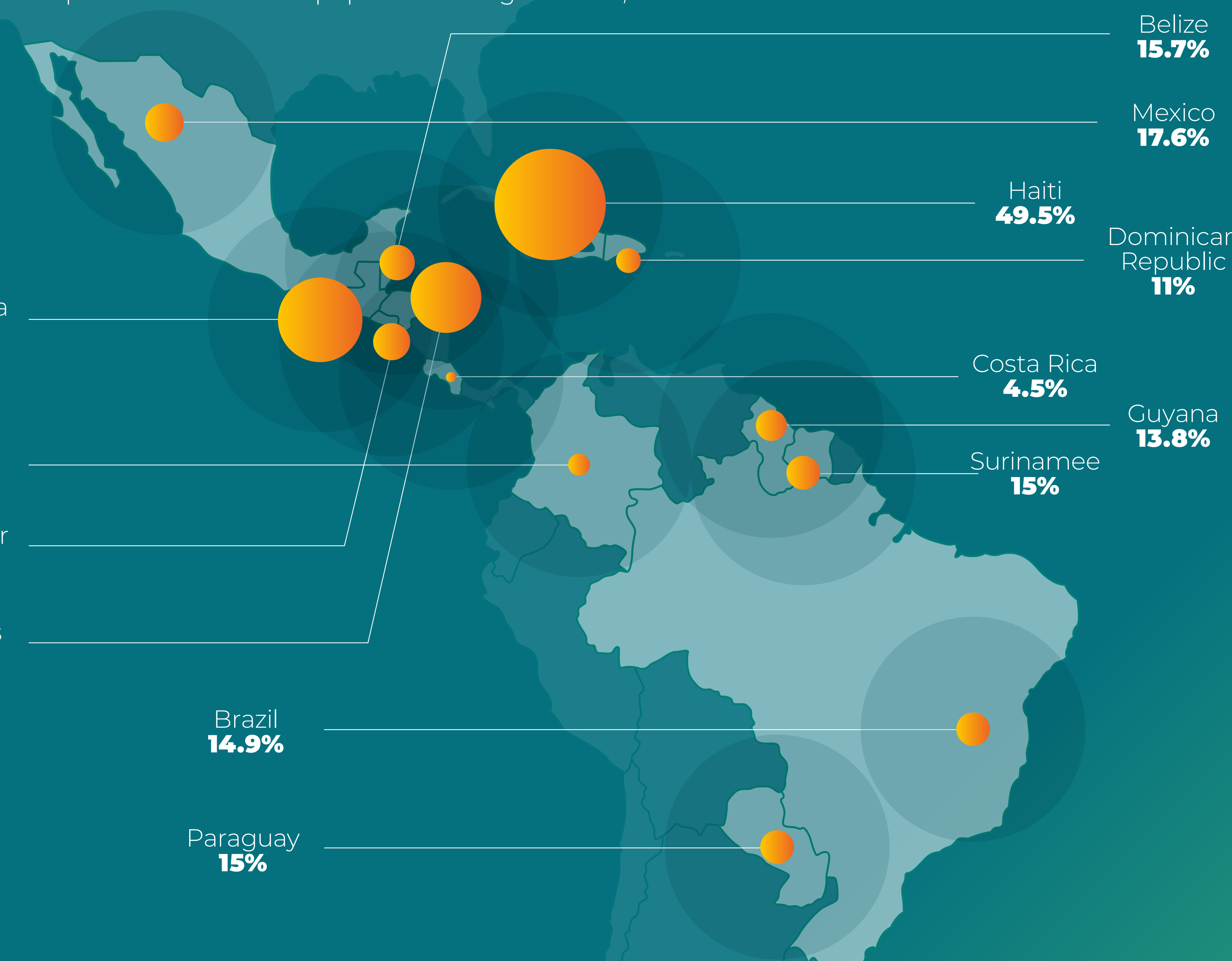
1. The necessary intersectoral coordination to facilitate the legal recognition of informal settlements (property titling), so that transmission and distribution networks can be adequately extended;
2. The implementation of rate and contracting reforms that facilitate access for users who are currently informal; and
3. The intensive use of technological advances, such as prepaid meters.

However, it should be noted that irregular electricity consumption is linked to more than just vulnerable areas and informal settlements. For example, it is estimated that 50% of the cost of electricity loss (approximately USD 40 million) in 2010 in Uruguay originated in non-poor areas (López Cariboni, 2019). Similarly, in Colombia's Atlántico, La Guajira, and Magdalena departments, substantial electrical losses were identified in non-vulnerable segments. Although there is no exact breakdown of the cost of losses by segment, it has been reported that in these departments, the cost of losses during 2021 was USD 150–200 million (El Tiempo, 2022).

The reasons behind the energy losses originating in the non-vulnerable segments of users can be associated with the control capacity of electric utility companies. However, there are also explanations in political economy literature that can help understand this problem. The literature observes that, to the extent that tolerance towards electricity theft represents a widespread situation, such acts can also take place in other social groups, not necessarily those with fewer resources.

Box 2.1 Informal connections and settlements

Figure 2.1.1 Proportion of the urban population living in slums, 2018



Source: Own elaboration based on the World Bank's World Development Indicators.
Note: The figure shows the percentage of the urban population living in slums in 2018. The data for Brazil corresponds to the year 2016.

In developing countries there are segments of the population that depend on irregular access to energy. Although measuring coverage is methodologically difficult, a proxy used is the population living in marginal areas or in irregular settlements (Butera *et al.*, 2016). According to the World Bank's World Development Indicators, in 2020 around 18% of the population of Latin America lived in slums. However, there is marked diversity between countries. For example, the population in marginal areas is estimated to be in the order of 9.7% in Colombia, 37.7% in Guatemala, 48.9% in Haiti, 17.6% in Mexico and close to 15% in Paraguay.

Consequences of electrical losses

There are various supply and demand mechanisms through which increases in electrical losses influence the efficiency of electric power systems. In the first case, the system may require a greater generation capacity to cover the energy losses produced in the transmission and distribution. Therefore, measures meant to reduce technical losses can also lead to improvements in the efficiency of the electric power system. Such measures can reduce the need to increase electricity generation, which in turn produces environmental benefits. On the demand side, non-technical losses imply unbilled consumption, potentially leading to excessive electricity consumption.

Regardless of whether the losses are technical or non-technical, they increase the energy demand that an electric power system must meet. Technical and commercial losses can produce a significant energy demand that must be met either by the generation system or through imports. Chapter 3 analyzes these losses, which are significant and represent an overuse of energy resources that generate additional costs for the entire electricity supply chain.

From an environmental perspective, actions aimed at reducing and controlling electrical losses constitute mitigation measures against climate change. In line with the above, as Surana and Jordaan (2019) rightly point out, electrical losses contribute to compensatory electricity generation, that is, additional electricity generation intended to compensate for the inefficiency of the electricity market. The carbon footprint of losses depends on the technologies that constitute the generation system in each country.

A reduction in electrical losses also implies an increase in income due to higher billing. This can contribute to strengthening the financial capability of public services to make investments and improve the system's sustainability. The financial burden of electrical losses not only affects the investment capacity of utility companies and the quality of the services they provide but also tends to cause fiscal transfers from governments to electric utility companies, thereby sacrificing resources that could be allocated to other priority areas for the population.

The different effects of technical and non-technical losses are worth noting. Given that the determining factors of one and the other are essentially different, the effects of a reduction in loss levels can also be grouped or classified in a differentiated manner. These considerations are relevant when defining reduction, management, and control plans. Although changes in technical losses will affect, for example, the geography and demand patterns of the service areas, they are fundamentally closely related to the efficiency of the energy transport system. Infrastructure improvements primarily translate into net energy savings. On the other hand, non-technical losses are strongly influenced by the institutional framework or organization of electricity markets, as well as external factors such as economic crises. Therefore, reductions in energy losses generally lead to a partial normalization of energy consumption, which was previously not recorded during billing.

Despite the above, there is certainly a complementary relationship between the measures to reduce technical and non-technical losses. This is why electricity transmission networks, transformers, and macro-meters in good condition also constitute the basic infrastructure for controlling and managing potential non-technical losses.

Non-technical losses involve unbilled and potentially excessive consumption.

2.3 Institutional factors

The underlying factors discussed in this chapter are the institutional frameworks that govern the electricity markets. Regulatory frameworks and corporate governance schemes are essential for sending the right signals and reducing electricity losses. Transparent pricing and incentive systems have been shown to help promote regulation control by electric utility companies. In both transmission and distribution, in countries such as Chile, Colombia, Costa Rica, and Peru, price schemes reward or penalize high or low performance based on pre-established goals. Similar pricing policies have been implemented in the large metropolitan areas of El Salvador, Guatemala, Panama, and Uruguay. For example, under these regimes, the regulator allows companies to include the costs of losses in their electricity rates up to 7%. If the losses exceed this level, the companies must absorb the costs, with the consequent direct reduction in their income. These experiences are discussed in **Section 5.**

Independence in electric utility company governance is essential to establishing the necessary incentives for promoting the control of losses and improving the operational soundness of the system. With the support of an adequate institutional and regulatory framework, public and private electric utility companies have managed to reduce their losses in countries such as Costa Rica and Trinidad and Tobago (public systems) and Chile and Peru (where private initiatives are predominant). However, relatively high levels of losses are still observed in countries with greater public participation, indicating the need to strengthen the management schemes of public service companies. See **Chapter 4.**

2.4 Conclusions

This chapter provides an overview of the topics covered in this book and presents a series of definitions that will be utilized in subsequent chapters. It also offers a qualitative examination of the problem of electricity losses, delineating the interconnections between their causative factors and implications. A crucial insight gleaned from this chapter is that, in numerous instances, both the causative factors and consequences of the energy loss problem extend beyond the confines of the technical domain of the electric power system.

Indeed, the level of energy losses constitutes a central measure of the performance of electric utility companies and the system as a whole. It directly reflects a key measure of the electric power system's operational, commercial, and financial management. Although their determining factors and consequences may fall outside the scope of the technical measures adopted by companies in the sector, these measures are essential for controlling and reducing such losses. For example, investments in expansion, modernization, and maintenance of the management, transmission, and distribution infrastructure are unavoidable.

However, the effectiveness of these investments can be diminished by a wide variety of factors, including the socioeconomic characteristics of the areas where the electricity service is provided, the institutional environment, and even economic shocks. Therefore, diagnosing and designing measures to address the problem of electrical losses requires a coordinated multisectoral vision. A key dimension in constructing this vision is the regulatory and institutional framework, which seeks to increase the transparency and independence of electric utility companies.

The interrelationships between the determining factors of losses in each context, added to the intrinsic complexity of electric power systems, call for developing loss reduction strategies that consider each reality's characteristics and particularities. The first step in developing such strategies is to provide sufficiently detailed quantitative information on the types of losses (technical and non-technical).

In short, the map of the determining factors and consequences of electrical losses highlights the factors intrinsic to electric power systems and the multidimensionality of the underlying factors that determine such losses. More importantly, reducing and controlling loss levels is unavoidable for achieving a financially and environmentally sustainable electric power system.

The management of electrical losses requires a multisectoral approach and customized strategies, underpinned by detailed quantitative analysis.

Chapter 3

What is the magnitude of the problem?

One of the most notable restrictions in understanding the problem of energy losses in the region is related to the need for comparable information between countries. If something cannot be measured, it cannot be improved upon. This chapter has been written to gather and reconcile data from various sources to quantify the issue of electricity losses while simultaneously examining the standing of Latin America and the Caribbean in relation to the rest of the world. Furthermore, this chapter aims to provide an understanding of the magnitude of the problem and discuss its implications and consequences in terms of financial, environmental, and service quality.

The analysis presented in the following pages indicates that the problem of electrical losses in the region is of utmost relevance because it reflects one of the most pronounced deficiencies in the Latin American energy sector. To the extent that energy losses constitute a core measure of the performance of the electrical industry, the results shown here indicate enormous opportunities to improve the efficiency and sustainability of electric utility companies.

The measurement approach follows the outline presented in Chapter 1 to provide a homogeneous view of regions and countries. Therefore, available electricity refers to the energy that enters the electric power system grids for use by end users, including gross generation, net imports, and isolated production, whereas end users include residential, industrial, and commercial users, and other clients (see Box 3.1). It should be noted that in this chapter, the losses analyzed are those of the electric power systems in each country. This means that losses do not refer to those observed at the level of electric utility companies unless otherwise indicated.

Despite restrictions in data homogeneity across countries, this analysis consolidates information with the goal of quantifying the magnitude of the electrical loss problem and determining its financial, environmental, and service quality impacts.

Box 3.1.
Approach to measuring electricity losses

Ideally, electricity losses should be analyzed according to their classification (technical or non-technical) at each stage of the electricity system chain and by user type. This makes it possible to track the main causes and consequences. Nonetheless, it is challenging to gather consistent data across different countries due to the diversity of electricity systems and the challenges associated with measuring non-technical losses in distribution.

In this context, the main challenge in obtaining a general overview of electricity losses is the availability and reliability of information in each country of the region. The estimates of losses at the aggregate country level presented in this book are based on official information. The database analyzed includes information from regulatory agencies, ministries, and the Economic Commission for Latin America and the Caribbean (ECLAC).

When information was unavailable from the previously consulted sources, the data provided by the International Energy Agency (IEA) were used. This source also offers the advantage of facilitating comparisons with countries outside of the study region. Own estimates are used as a last resort and are based on information from the official balance sheets, representative electricity companies, and the IEA. Agencies consulted for electricity price information include the Regional Energy Integration Commission (CIER) and the Latin American Energy Organization (OLADE). To provide comparable data, losses were estimated according to Table 3.1.1.

The final sample used in Chapters 3 and 4 for the period 1990-2019 consists of 140 countries, including 26 from the region, which are classified according to their income level according to the World Bank Country Classification (from 2021).

In order to eliminate anomalous years, the ratios were computed as five-year averages. Additionally, the regional or income-level averages were determined by averaging the country-level ratios to prevent the overrepresentation of larger economies.

Table 3.1.1 Indicators of electrical losses

TL	**Transmission losses**	=	$\frac{\text{Transmission losses}}{\text{Available energy}}$	=	$\frac{\text{Available energy-Delivered}}{\text{Available energy}}$
DL	**Distribution losses**	=	$\frac{\text{Distribution losses}}{\text{Available energy}}$	=	$\frac{\text{Delivered-Billed}}{\text{Available energy}}$
L	**Total electricity losses**	=	TL + DL	=	$\frac{\text{Available energy-Billed}}{\text{Available energy}}$
TLD	**Technical losses in distribution**	=	$\frac{\text{Technical losses}}{\text{Available energy}}$		
NTLD	**Non-technical losses in distribution**	=	$\frac{\text{Non-technical losses}}{\text{Available energy}}$		

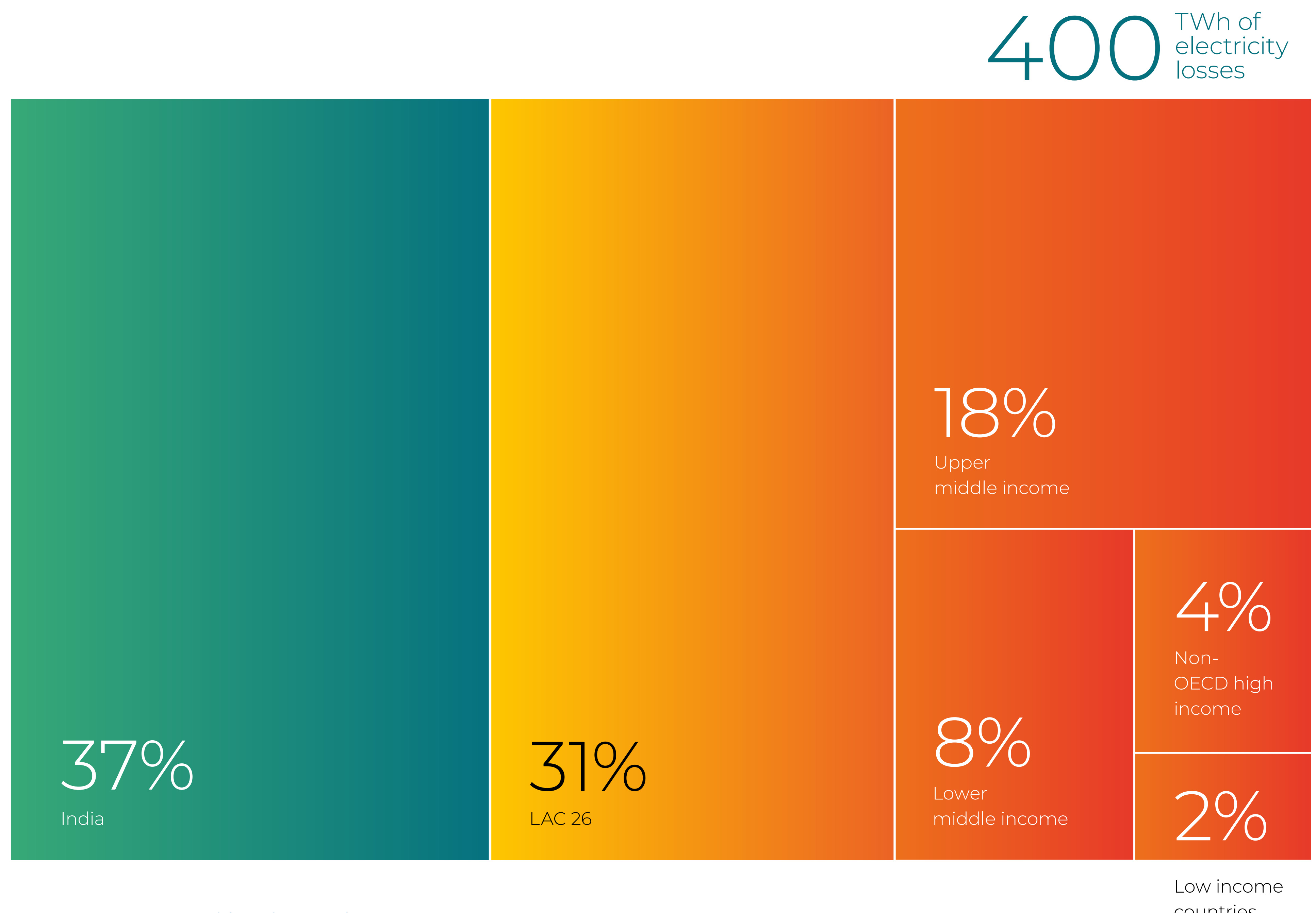
Source: Prepared by the authors.

3.1 A global perspective

Electricity losses in transmission and distribution systems are a global problem present in all regions of the world to a greater or lesser extent. It is estimated that the world loses approximately 400 TWh of energy annually. This is equivalent to the electricity consumption of Mexico and Chile in 2019 (see Figure 3.1). Figure 3.1 shows how that amount of energy is distributed by geographic region. It is worth noting that energy losses are lower, despite electricity generation in high-income regions being notably higher. In terms of the amount of energy lost, the Latin America and Caribbean (LAC) region is second only to India.

The magnitude of the problem depends on the levels that are considered economically feasible to be recovered. The estimations presented in this and subsequent chapters use an ample reference level, in the order of 10%, above which inefficient losses are considered. The electricity lost can be approximately four times greater for higher efficiency levels, between 6% and 5%. For example, using data from 2016, Surana and Jordaan (2019) estimate global electricity losses in the order of 1729 TWh/year.

Figure 3.1 Distribution of the electricity losses of countries by income level, 2019



Source: Prepared by the authors.
Nota: The electrical losses presented in the figure are those that exceed 10% of the total available energy. High-income OECD countries lose less than 1%.

It is important to highlight the considerable heterogeneity present at both the regional level and within the countries themselves. In developing nations, non-technical losses range from 10% to 40% of the total generation.

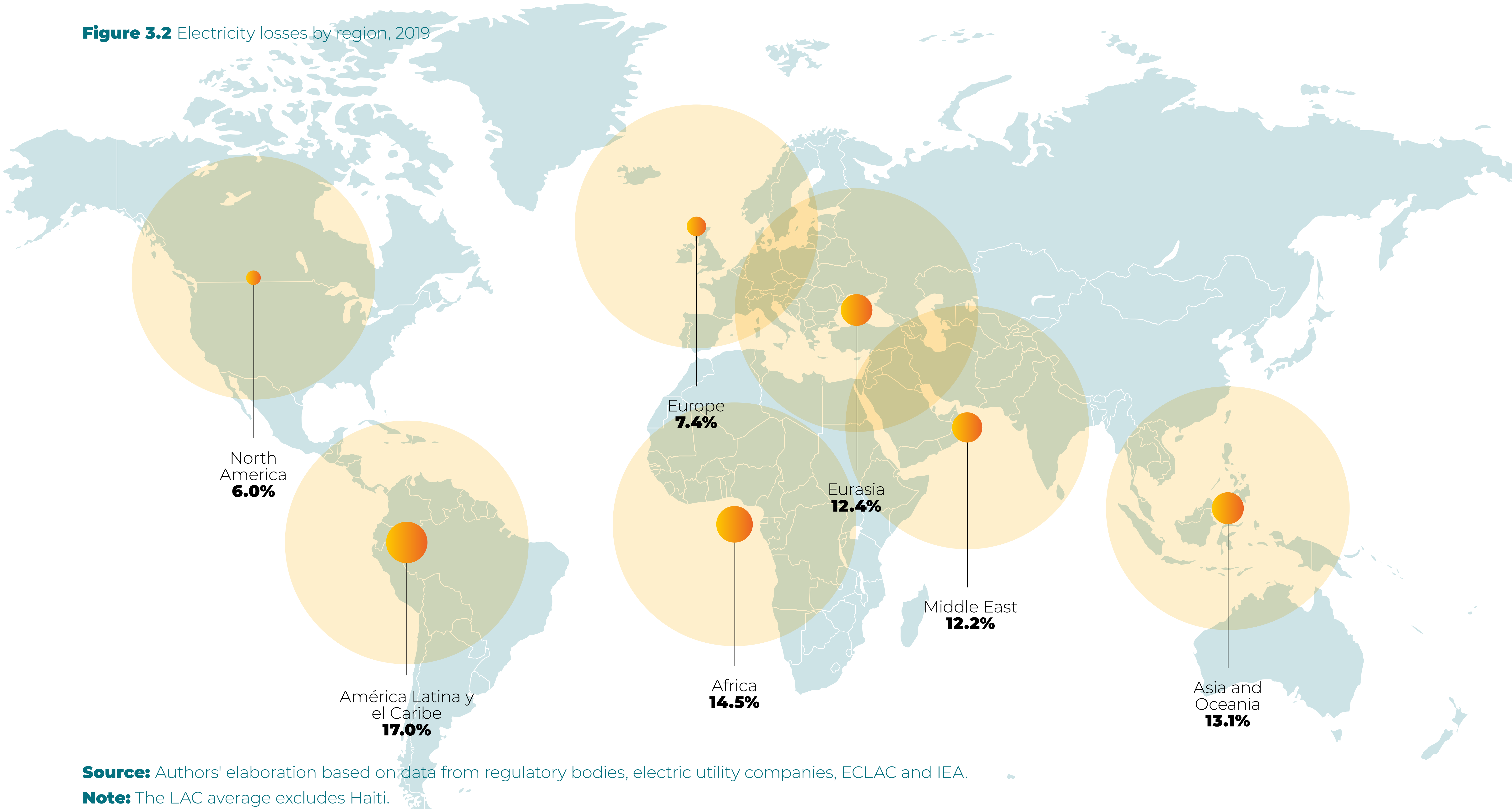
Regardless of the efficiency levels considered to estimate the losses that need to be recovered, Figure 3.1 emphasizes the substantial magnitude of the problem, as well as the regions and countries in which policy actions should be concentrated. In this figure, it is striking that both India and LAC each constitute approximately one-third of the energy lost globally. Taking into account the immense population differences between the two, Latin America and the Caribbean certainly stands out as a region that deserves special attention.

It should be noted that there is great diversity within regions and even within countries themselves. In developing countries, non-technical losses can range from 10% to 40% of total generation (Smith, 2004). Even in the United States (US) and Europe, states and electric utility companies can be found with losses that exceed efficiency levels. For example, in the US, there are states where losses lie between 8% and 13.3% (Wirfs-Brock, 2015). In Europe, a group of countries (e.g., Kosovo, Montenegro, North Macedonia, and Serbia) presented loss levels of more than 12% in 2018 (CEER, 2020).

Figure 3.2 shows each country's average loss indicator as a percentage of the available energy. The indicators confirm the gap between the LAC region and the rest of the regions in the world. While average electricity losses in North America were estimated at around 6%, average losses for Latin America and the Caribbean amounted to 17%. Thus, LAC was the region with the highest electricity losses on average, followed by Africa (15%), Eurasia (12%), Asia and Oceania, and the Middle East (with 13% and 12%, respectively).

One of the most concerning indicators is not the levels observed in recent years but rather the trends that have emerged over the past three decades (see Figure 3.3). While there has been a notable downward trend in loss levels in upper-middle and upper-income countries and high-income OECD countries, this trend is not as pronounced in LAC and low-income countries. In particular, over the past three decades, the electricity loss indicator in LAC has remained consistently high, hovering around or above 17%.

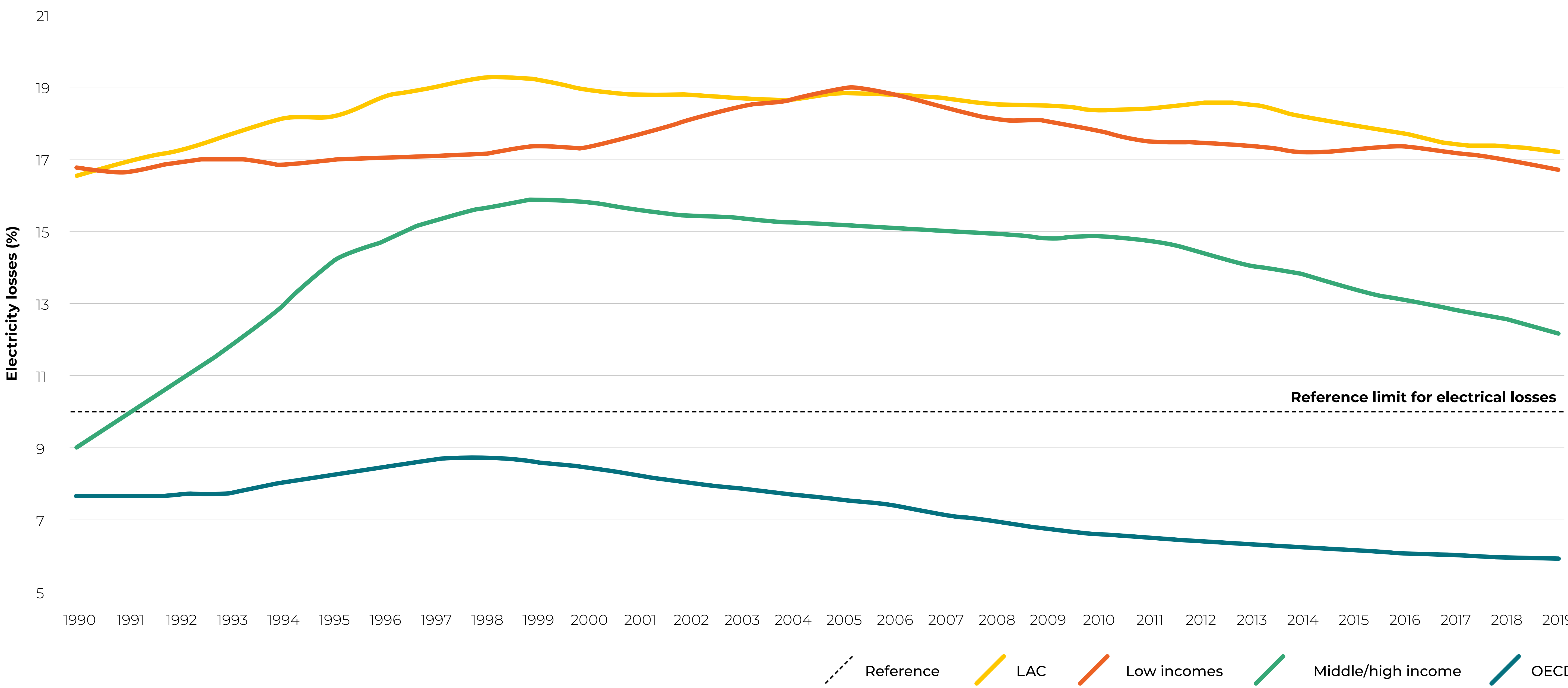
Figure 3.2 Electricity losses by region, 2019



Source: Authors' elaboration based on data from regulatory bodies, electric utility companies, ECLAC and IEA.

Note: The LAC average excludes Haiti.

Figure 3.3 Evolution of electricity losses, 1990–2019



Source: Authors' elaboration based on data from the International Energy Agency.

Nota: The figure shows the 5-year moving average of the loss percentage. Low income includes low- and middle-income countries. The classification by income level follows the World Bank 2021 classification. Groupings of countries by income level exclude LAC and OECD countries.

3.2 Electricity losses in Latin America and the Caribbean

The magnitude of the problem

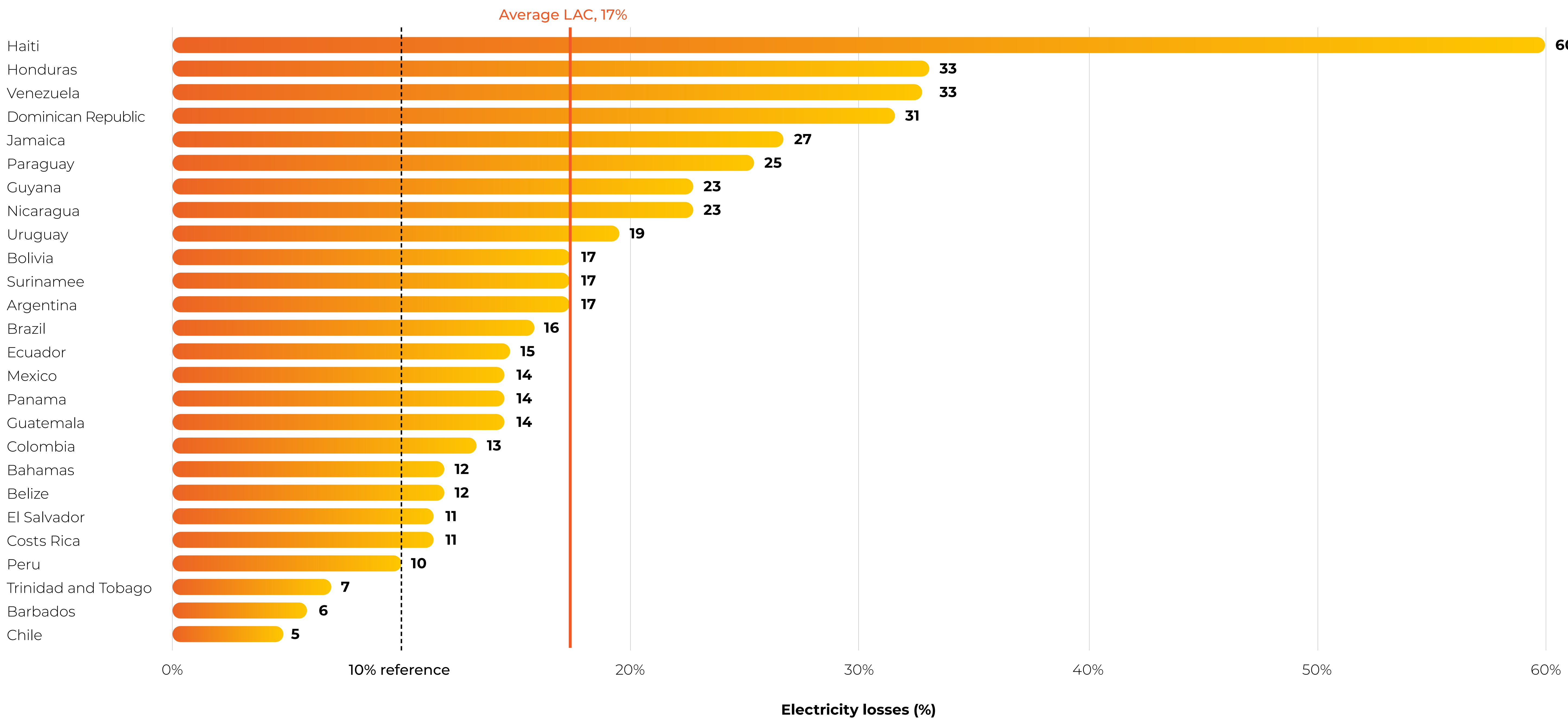
This section offers a more detailed examination of intra-regional differences based on 26 LAC countries. Figure 3.4 shows annual electricity losses as a percentage of the total available electrical energy. Significant variations are observed between countries, from 5% in Chile to 60% in Haiti. Most countries showed losses above the reference level for acceptable losses (10%, green line).[6] Nevertheless, three of the 26 countries had low levels of losses. Peru has a loss level close to the efficiency reference level.

These figures suggest that measures aimed at reducing electricity losses would have positive economic effects on the LAC electricity industry. However, reducing loss levels beyond a certain minimum is not always feasible. This means that even when reducing losses to zero percent is desirable and technologically possible, it is generally not economically viable. Against this backdrop, it is evident that the region is far from reducing loss levels to the minimum desirable level, as has been achieved in some high-income countries.

Electricity losses are a major problem in all LAC subregions, where their average rate per subregion ranges from 15.2 to 18.1. Figure 3.5 shows the most and least affected countries by sub-region. In equivalent terms, Venezuela lost approximately 31 TWh, the highest value in the Andean subregion, equivalent to two-thirds of the country's net electricity production generated from fossil fuels. Honduras, which is at the top of the list of Central American countries, registers losses equivalent to total hydroelectric generation. Losses in Jamaica and Paraguay exceed 25%, an equally worrying figure in the context of the Caribbean and Southern Cone regions, respectively.

6. For a comparison of electricity losses among the 10 largest electricity producers during 2016 (China, United States, India, Russia, Japan, Canada, Germany, Brazil, Korea and France), see IEA et al. (2019).

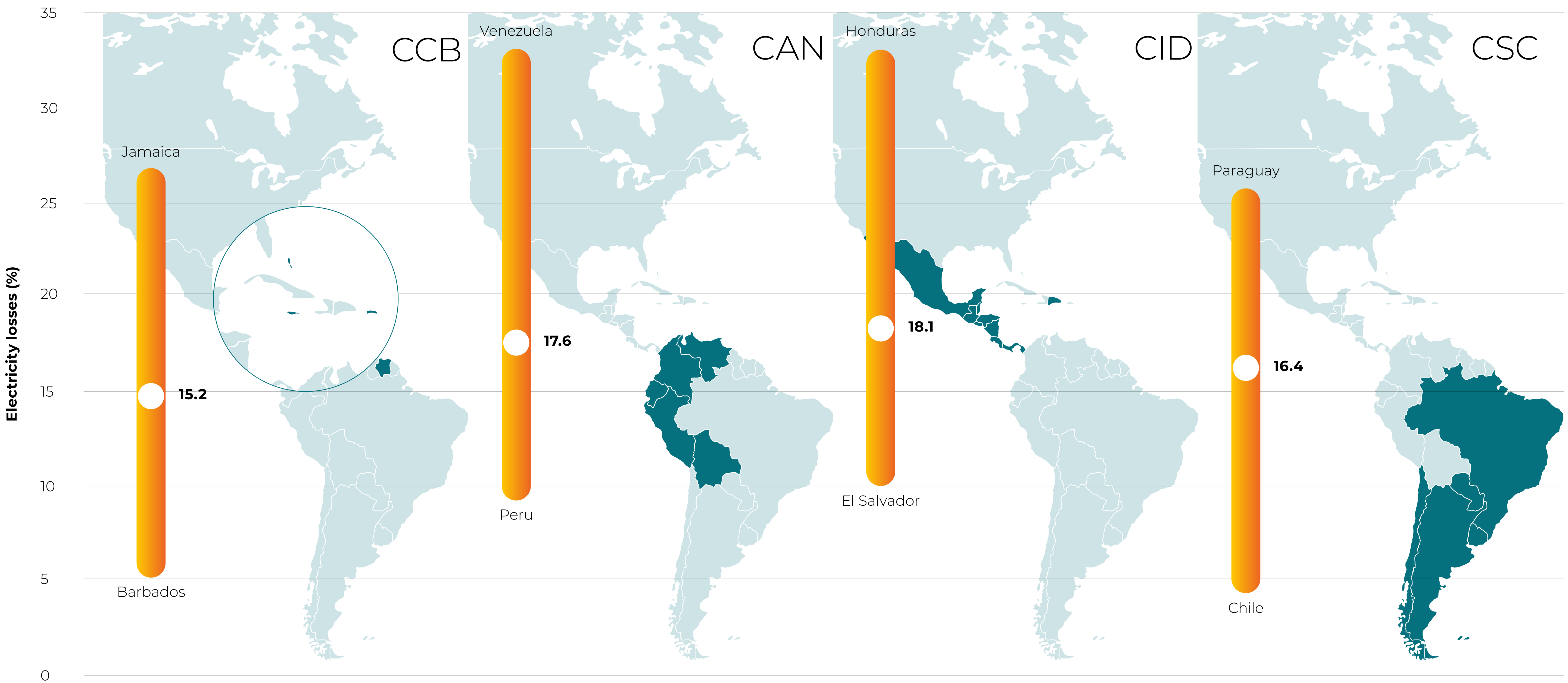
Figure 3.4 Electricity losses by country



Source: Authors' elaboration based on data from regulatory bodies, electric utility companies, ECLAC and IEA.

Note: The figure shows electrical losses as a percentage of available energy. Average of the information available for the last five years: 2015–2019. The LAC average does not include Haiti.

Figure 3.5 Losses by subregion in Latin America and the Caribbean



Source: Authors' elaboration based on data from regulatory bodies, electric utility companies, ECLAC and EIA.

Note: The figure shows electrical losses as a percentage of available energy. Average of the information available for the last five years: 2015–2019. Countries of the Caribbean (CCB), Southern Cone (CSC), Andean Group (CAN), Central America, Mexico, Panama and the Dominican Republic (CID). Haiti is not included, and only the latest available year was used for the Bahamas.

How have losses evolved in LAC countries?

Figure 3.6 displays the recent evolution of electrical losses by country. Specifically, the chart presents the indicator of annual electricity losses and their variation over the last five years, considering the available data.

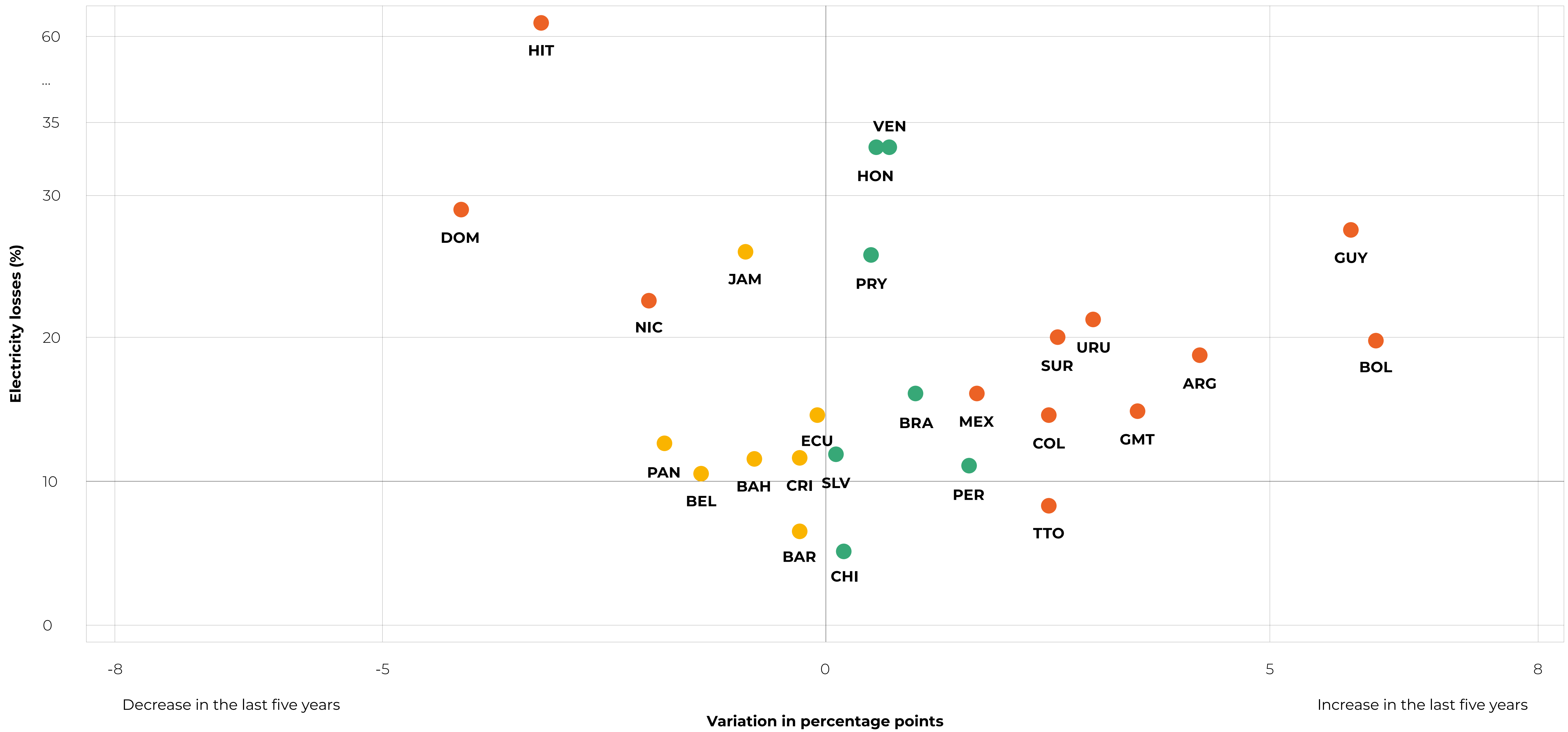
Countries in the upper-left quadrant have reduced their loss levels, although most remain high. Despite the efforts made, countries in said quadrants with high levels of losses (for example, above the LAC average of 17%) have tended to present relatively modest improvements. This group includes a diverse group of countries such as Nicaragua, the Dominican Republic, and Jamaica.[7]

The countries in the upper right quadrant face the most difficult situation since they present high levels of losses and have also experienced increases in recent years. A worrying aspect is that practically half of the countries under analysis have shown an increase in losses in recent years. The countries in this group include Guyana, Bolivia, Uruguay, and Argentina.[8] Note that this trend was observed before the COVID-19 pandemic (before 2020). During the pandemic, countries tend to experience greater challenges in terms of controlling their levels of electricity losses, which, in most cases, have increased. The following section will comment on the trends observed during this period.

Even in countries where losses are relatively low, some distribution companies face considerable challenges due to the socioeconomic or geographic conditions of the areas they serve. For example, companies in El Salvador and Peru, which provide services in rural areas with low population densities, register markedly higher loss rates than the country average. However, it should be noted that electricity losses can also be concentrated in high-density areas, as in the case of Mexico and Uruguay.

7. In this context, it is worth mentioning the recent efforts registered in the Dominican Republic, where the IDB (project DR-T1179) and other international financing sources committed nearly US$400 million to strengthen the program to combat electricity losses. This program was concentrated mainly in urban areas and was carried out through improvements in substations and transmission and distribution networks. In the last five years, this country has reduced its losses by around six percentage points. A similar effort, with significant improvements in the period of analysis, is recorded in Nicaragua. This country has reduced its loss rate by six percentage points during the period 2014-2019. Recently in Jamaica, the IDB (through project JA-T1206) is collaborating with the government to identify potential opportunities to decarbonize and provide technical support for the electricity sector, including loss reduction. In this country, the losses represent around 28%, of which 20% are non-technical losses, and since the losses are indexed in the rates, they cause high electricity prices and affect the competitiveness of the productive sectors..
8. In these countries, the IDB supports projects to reduce technical losses. In the case of Guyana, the IDB (project GY-L1066) has financed US$21.16 billion for the implementation of strategies aimed at improving energy efficiency and effectiveness, by reducing technical losses and improving the quality of service to consumers. in Guyana. In Argentina, the IDB (AR-T1267) provides technical and financial support to strengthen the resilience and reliability of the electrical system in order to reduce technical losses and GHGs.

Figure 3.6 Recent changes in electricity losses in Latin American and Caribbean countries, 2019



Source: Authors' elaboration based on data from regulatory bodies, electric utility companies, ECLAC and EIA.

Nota: The figure presents the country's loss ratio in 2019 and its variation over the last five years (x-axis). When information was not available, we used data from the nearest year.

Where do electricity losses occur?

Figure 3.7 shows the distribution of losses according to their location. Most of the electricity in LAC is lost in the distribution system, most likely because of non-technical factors. Based on the information available, distribution losses account for approximately 80% of the total losses registered in the 15 LAC countries. According to technical reports,[9] technical losses in distribution are concentrated mainly in rural areas, which represents a challenge for companies that provide services in areas with low population density.

On the other hand, the transmission losses are relatively low, ranging from 1.9% to 3.5%. The exceptions were Peru and Paraguay, which represented approximately 5%. Paraguay faces the challenges of high technical and non-technical losses, insufficient infrastructure, and the need to update and modernize electric power systems, among others. More importantly, these limitations have negatively affected the quality of the services offered to the population, which is more frequent and severe with the increase in demand and during peak hours.[10]

It is worth mentioning that the patterns mentioned above in the LAC are similar to those observed in other regions. Electric power systems in other regions also register relatively low transmission losses versus losses that occur in the distribution. For example, in Europe, transmission losses ranged from approximately 0.5% to < 3% in 2018 (CEER, 2020). Conversely, most European countries' distribution losses fall between 2% and 10%. Nevertheless, it is crucial to recognize that a direct comparison of transmission subsectors between countries is not entirely feasible due to variations in their definitions. For instance, while some countries' transmission networks encompass lines starting at 130 KV, others include lines with voltages exceeding 230 KV.

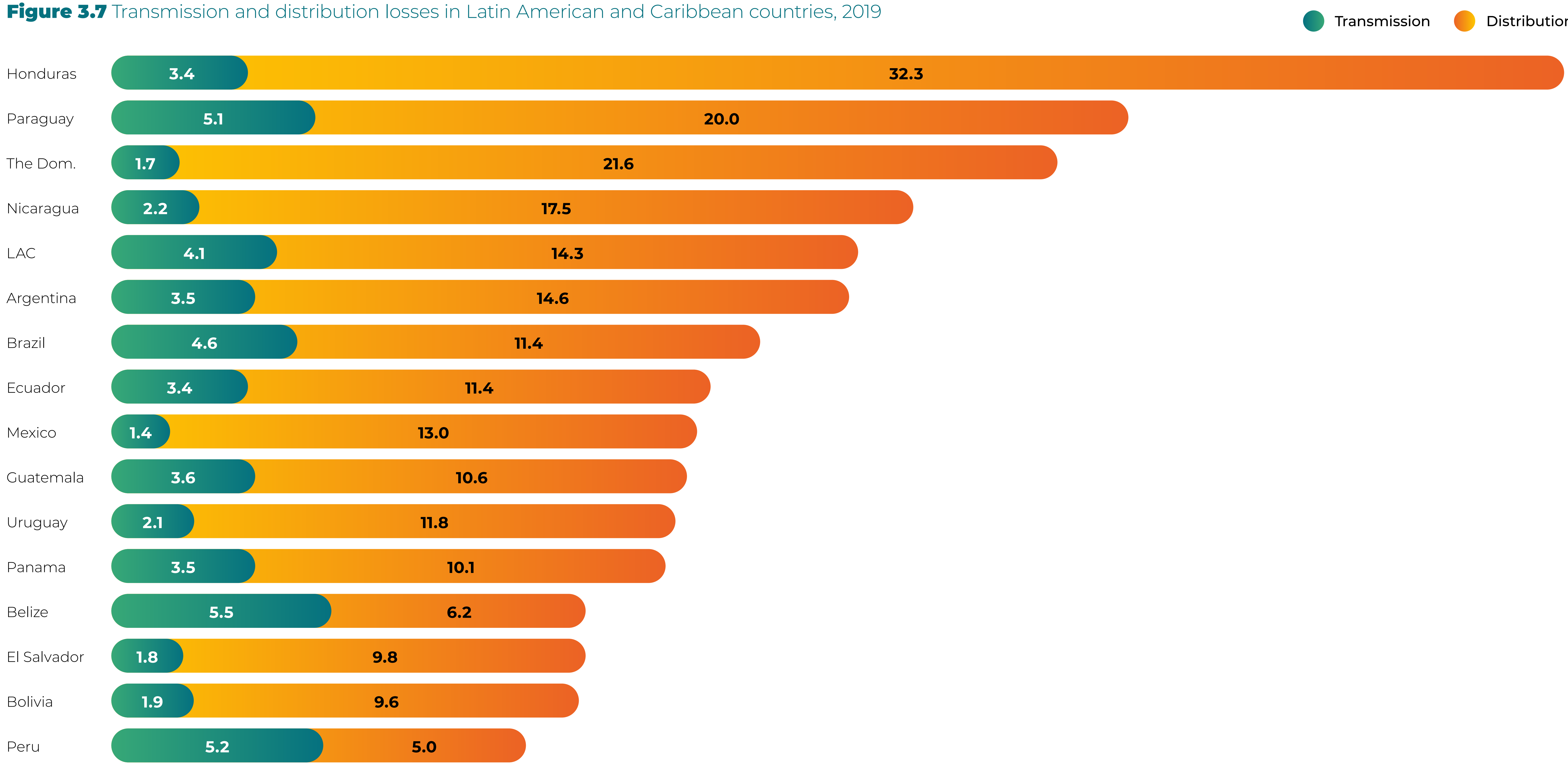
3.3 Implications for the region

The energy lost in transmission and distribution systems represents financial, environmental, and service quality costs that electric utility companies, governments, and end users must face. This section provides an estimate of these costs to reveal the other side of the coin. However, the costs of electrical losses can go beyond those explored here.

For example, since losses are energy that goes unbilled, they can discourage energy conservation practices or the adoption of more energy-efficient appliances by users who do not pay for the service, leading to higher energy demands. In turn, this additional demand may require greater investments in generation and transmission, representing costs that ultimately must be passed on to society. Furthermore, high losses can even discourage investment in the electricity sector in extreme cases. This section, therefore, offers a partial and conservative estimate of the social cost of electrical losses.

9. For example, the Mexican Ministry of Energy — in its national electric power system development program 2022–2036 — estimates a three-fold increase in the operational efficiency of distribution networks in rural areas compared to urban areas by reducing technical losses. The ANEEL report (2021) points out that the regions with the highest rates of technical losses in Brazil are the north, followed by the northeast and the central west, the regions with the lowest population densities.
10. See, for example, ANDE's Institutional Strategic Plan, 2021–2026. Regarding the challenges faced by Paraguay, the IDB, in collaboration with other sources of international financing, is supporting the Multiphase Energy Transmission Program to improve transmission lines and substations, including the installation of the first 500 KV high voltage line.

Figure 3.7 Transmission and distribution losses in Latin American and Caribbean countries, 2019



Source: Prepared by the authors based on information from regulatory bodies and electric utility companies.

Note: The figure shows electrical losses as a percentage of available energy. The estimate for Brazil is based on a sample of electricity distribution companies.

What are the financial costs of electricity losses in Latin America and the Caribbean?

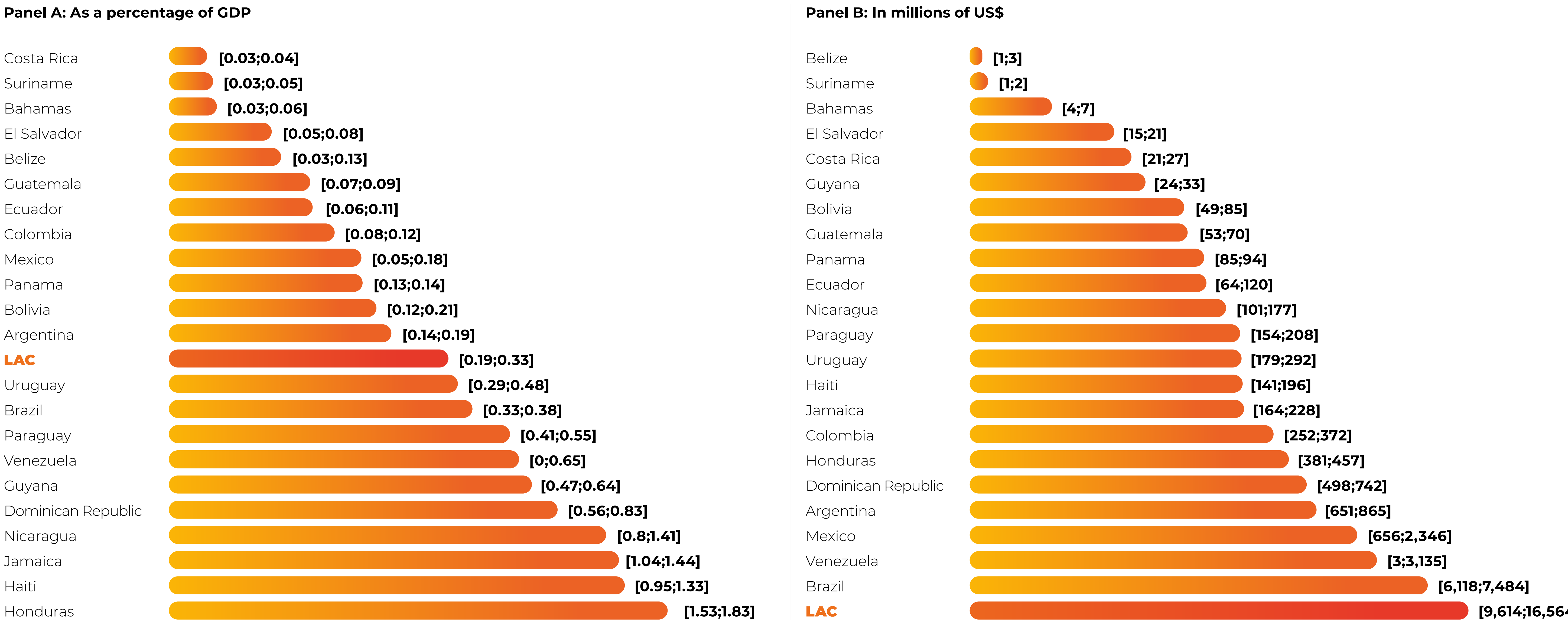
The most evident association is that electrical losses represent financial losses. Although the levels of these losses depend on multiple factors, the calculations performed in this study indicate that even under the most conservative assumptions, they are of a highly substantial magnitude. Indeed, our estimates indicate that the costs of electricity losses in LAC range between USD 9.6 and USD 16.6 billion annually, equivalent to approximately between 0.19% and 0.33% of the region's GDP. Of course, these regional percentages vary significantly between countries, depending on their observed loss levels and the characteristics of their electricity generation mixes. Figure 3.8 shows these magnitudes as a percentage of the GDP for each country. It shows that the cost of losses can fluctuate from 0.03% (Costa Rica) to 1.8% (Honduras).

On the one hand, in general terms, these figures approximate the income that electric utility companies fail to receive for the services provided, which negatively affects their financial sustainability. However, such losses represent a considerable opportunity cost to society. For example, annual financial losses are comparable to the expenses incurred by the largest social programs in the region. For example, in Brazil, losses represent a minimum estimated cost of 0.3% of GDP, equivalent to more than two-thirds of the budget allocated to the Bolsa Familia program.[11] Similarly, electricity losses in Mexico represent between 0.05% and 0.18% of its GDP, comparable to the budget of the Youth Building the Future program (which represented around 0.08% of GDP in 2021).[12]

In any case, the direct monetary cost derived from the current situation constitutes an unsustainable situation if the region hopes to overcome the challenges it faces today to cover its infrastructure investment needs. This situation is even more alarming because, in recent years, there has been a reduction in investment in the electricity sector, thereby widening the latent investment gap in the sector. Between 2016 and 2021, depending on the investment needs scenarios taken as a reference, the investment gap (insufficient investment) in the electricity sector can fluctuate between USD 10 and USD 78 trillion. This means that, regardless of the estimated level of investment needs, reducing the levels of energy losses would contribute to reducing the investment gap (see Box 3.2).

11. The Bolsa Família Program (PBF) is a conditional cash transfer program that aims to support families in poverty or extreme poverty.
12. The Youth Building the Future program aims to get young people into the labor market through training and financial support.

Figure 3.8 Financial cost of electricity losses in Latin American and Caribbean countries



Source: Prepared by the authors based on information from regulatory bodies and electric utility companies, ECLAC and IEA. GDP data by country were obtained from the World Bank Development Indicators database.

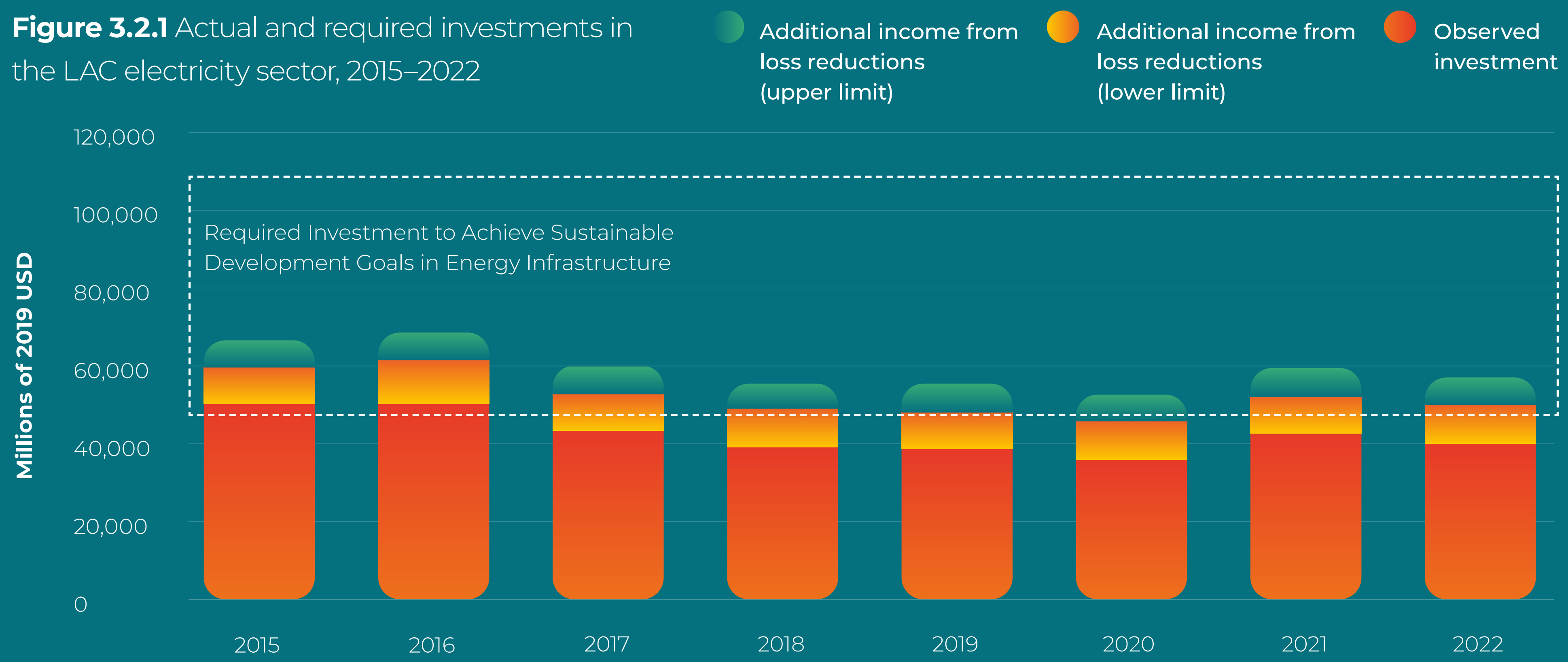
Note: The figure provides the estimated range of electrical losses in monetary terms. The lower and upper limits of this range come, respectively, from the minimum and maximum electricity prices for the end-user in the industrial, residential, and commercial categories. The figure is on a logarithmic scale arranged by the mean of the estimated cost. These costs have been cLACulated only for countries that present losses of more than 10%. The estimated are based on the average losses during the last 5 years with information available prior to 2019 (included).

Box 3.2
Investment needs in the electricity sector

The countries of LAC are facing a complex challenge to close the infrastructure investment gap. In the last decade, infrastructure investment has decreased as a percentage of GDP (Cavallo et al., 2020). In recent years (2021 and 2022), investment in the electricity sector has only partially recovered, and its levels are still approximately 15% lower than those observed in the mid-last decade. The problem is even more significant in terms of investment in electricity distribution and transmission infrastructure, which has been reduced by approximately 40% from 2015 to 2021. IEA (2022) suggests that the drop in investment is largely related to many utilities' deteriorating financial situation, high electricity losses, and the limited fiscal capacity of governments. Thus, there is a high opportunity cost for companies to increase their financial sustainability by reducing losses.

This situation is particularly alarming in a region characterized by systematic underinvestment in infrastructure. Based on estimates made by Brichetti et al. (2021), Cavallo, Powell, and Serebrisky (2020), and Rozenberg, Julie, and Marianne Fay (2019), as well as estimates of investments made in the electricity sector, an indicative range of the evolution of the investment gap in the sector can be approximated. That is those pending investment needs for the LAC electricity sector. Figure 3.2.1 shows the evolution of investments in the electricity sector and the investments required to meet the sustainable development goals in energy infrastructure (as indicated in the area with the dotted line). The figure highlights that the sector's investment gap has grown recently. As seen in the figure, reducing the levels of losses can contribute significantly to reducing the investment gap regardless of the scenario considered.

Figure 3.2.1 Actual and required investments in the LAC electricity sector, 2015–2022



Source: Prepared by the authors based on IEA (2022), Cavallo, Powell, and Serebrisky (2020), Rozenberg, Julie, and Marianne Fay, eds. (2019), Brichetti, et al. (2021) INFRALATAM database, World Bank PPI database, and own estimates.

Note: Investment estimates for the electricity sector were acquired from the World Energy Investment 2022, INFRALATAM, and PPI databases. The investment requirement for this sector is defined within a range, with the lower limit corresponding to the figures provided by Brichetti, et al. (2021), and the upper limit based on the preferred scenario outlined by Rozenberg, Julie, and Marianne Fay, eds. (2019).

It is important to take these estimates with caution because the financial costs of electricity losses are susceptible to the prices at which they are valued. Under the approach of income not received by electric utility companies due to loss levels above 10%, this analysis values these "surpluses" at the current average prices of electricity services (for the reference period, see Box 3.3). Therefore, prices to the end customer below the recovery costs of providing the service may lead to underestimating the financial costs of electricity loss.

According to data gathered from 13 nations between 2011 and 2021, the estimated cost of losses falls within the range of USD 9,400–12,000.

However, even when considering different periods and valuation methods, the ranges estimated here align with the calculations reported by electric utility companies and other organizations. It should be emphasized that, although typically, the costs of electrical losses are not reported officially, situations have arisen in which official or journalistic media have reported them. Annex 1 compiles a set of statements for 13 countries between 2011 and 2021 and presents them in 2019. The amount derived from this compilation is in the range of USD 9,400– 12,000, matching the estimates presented in this chapter.

For example, according to reports from the Uruguayan Electric Utility Company (UTE), non-technical losses in the country were estimated to be approximately USD 177 million in 2013 and USD 200 million in 2021 (2019 dollars). In Honduras in 2012, ECLAC estimated that a reduction in technical and non-technical losses to a level of 12% would represent an additional annual income of USD 135 million,[13] while other sources indicated costs on the order of USD 507 million (in 2019 dollars).

Although the values reported in the media do not necessarily constitute homogeneous measures that can be compared between countries,[14] they confirm that the cost of electricity losses for Latin America and the Caribbean is extremely relevant financially for both electric utility companies and society.

13. This reference comes from the Energy and Natural Resources Unit of ECLAC. Electricity losses were valued at US$10 per MWh. On the other hand, the valuations presented in this study take averages (as of 2012) of residential, industrial and commercial prices of US$14.5, US$20.7 and US$23.9 per MWh respectively.
14. Indeed, the statements are heterogeneous in terms of the type of losses reported, which could be technical, non-technical or originate explicitly from theft.

Box 3.3
Approach to Estimating the Financial Cost of Electricity Losses

To estimate the financial costs, the losses were evaluated based on each country's residential, industrial, and commercial electricity prices. The minimum, average, and maximum prices for each country are used to determine the range of costs. These values were estimated from GWh lost above 10% of the total production available for the domestic market. Although this method represents a simplification, it makes it possible to estimate the magnitude of the financial losses generated mainly in the distribution. More accurate assessments may consider country-specific loss factors and distinguish between technical and non-technical losses in each electric power system flow phase. There are various alternative methods for assigning economic value to electrical losses.

1. Loss values are based on the cost of electricity generation and transportation. This means that they could be valued in relation to the marginal costs of generation and transportation, considering the technology used for production.

2. They can also be valued using energy exchange market prices. An advantage of this approach is that prices would reflect the economic value of energy, including the preferences of agents and the balance between supply and demand.

3. The cost of losses can be based on end-consumer prices (the method used in this report). Depending on the type of loss, prices can consider the supplier's margins. In particular, in the case of technical losses in the distribution subsector, prices could be based on the supplier's net margin.[15]

15. The cost of losses can vary significantly if they are valued at marginal generation costs during periods of high consumption. In particular, the cost of losses is relatively higher in countries where the generation mix is highly dependent on fossil fuels. In addition to generation costs, losses produce additional transmission costs related to the degree of efficiency of the transmission system.

More than money: Environmental impact

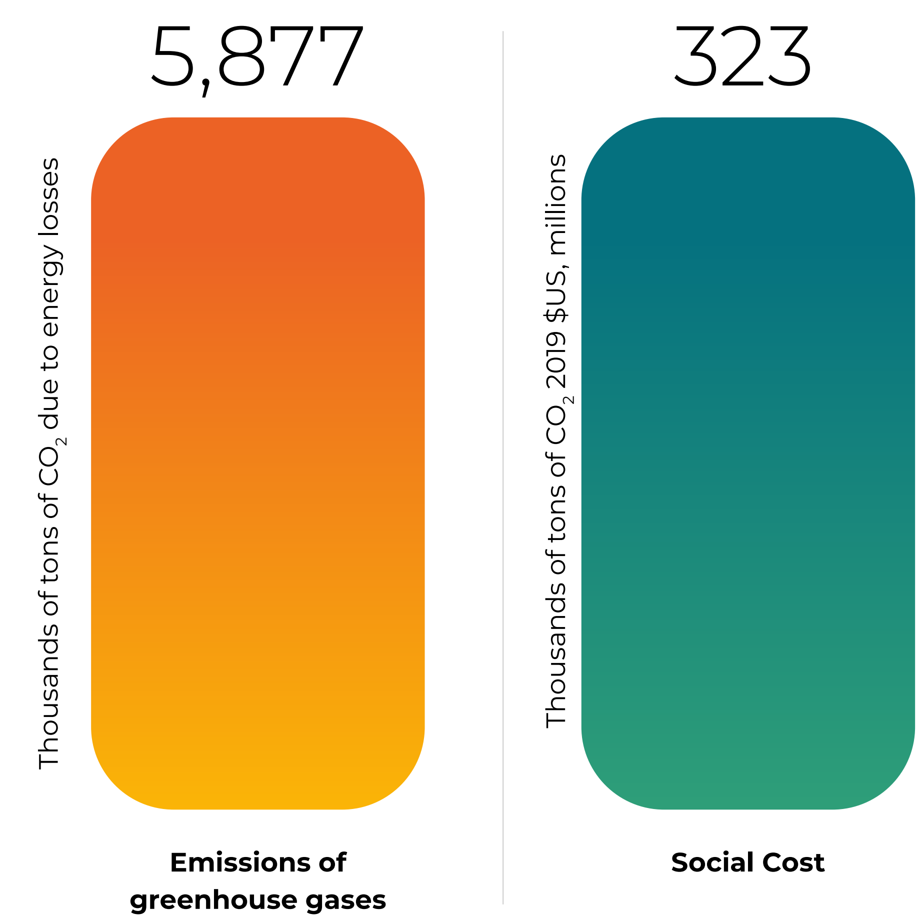
In the previous section, we indicated that the carbon footprint generated by electricity losses generally depends on the generation mix of each country. However, there are also two ways in which electrical losses generate greenhouse gas (GHG) emissions: on the one hand, the technical inefficiencies that lead to energy losses during transportation and on the other, the inefficient energy consumption of users when consumption is not measured and billed. Thus, under a loss-correction scenario striving for a level of 10% of available energy, for example, the energy savings that could be expected would result from a more efficient infrastructure and more significant energy conservation by users (whose consumption is measured and billed).

Under these considerations, the greenhouse gas (GHG) emissions associated with the electrical losses described in the previous sections are 5,877 thousand tons of CO2 per year.[16] This magnitude of polluting emissions is equivalent to 1.27 million gasoline passenger vehicles driven for one year, or 661 million liters of gasoline consumed yearly. In other words, such a level of annual emissions is avoided by approximately 8 GW of solar plants (PV) or 1,598 wind turbines operating for a year.

In monetary terms, the social cost of these excess emissions would be more than USD 320 million annually. Conservatively, this amount only represents the external factors associated with higher emissions, which could be attributed to the low levels of efficiency and low incentives for energy savings in the current situation. This amount is not included in the aforementioned financial losses.

Therefore, the carbon footprint of electrical losses is significant, and the measures taken to control and reduce them constitute climate-change mitigation actions. In line with what was stated at the beginning of the chapter, it should be noted that the emissions associated with electrical losses constitute a global problem that is generally overlooked. This omission has recently been emphasized by analyses prepared by two academics (Surana and Jordaan, 2019) and by the International Energy Agency. They have drawn attention to the environmental cost of these losses, estimating that the total losses in global transmission and distribution systems account for approximately one gigaton of carbon dioxide. Their estimates suggest that measures to reduce such losses could lead to the avoidance of approximately 400 million metric tons of carbon dioxide emissions per year. Box 3.4 comments on measures for reducing electrical losses as a climate-change mitigation measure.

Figure 3.9 Annual environmental cost of electrical losses in LAC



Source: Prepared by the authors based on data from regulatory bodies, electric utility companies, ECLAC and EIA.

Note: The figure is an approximation of the GHG emissions derived from energy losses and their social cost. The estimates are based on the assumptions laid out in Chapter 7.

16. The methodology for this estimation is found in Chapter 7.

Box 3.4
Reduction of electrical losses as a climate change mitigation measure

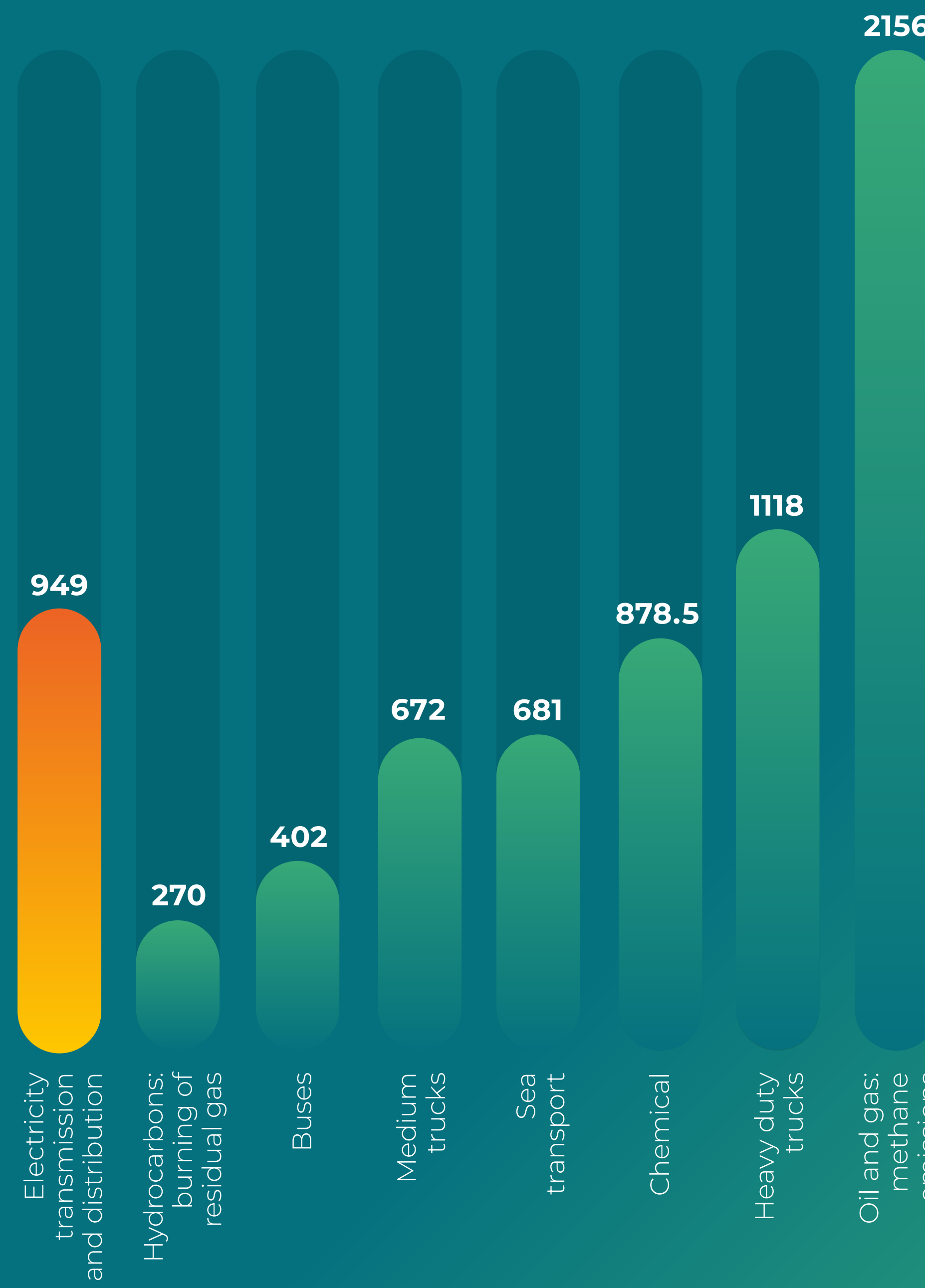
The magnitude of emissions associated with electrical losses in global transmission and distribution systems has been estimated in two recent analyses conducted by Surana and Jordaan (2019) and by the International Energy Agency (2020). These analyses emphasize the opportunity to act on the electrical loss front to mitigate the effects of climate change.

In the first study, Surana and Jordaan (2019) addressed electrical losses in transmission and distribution systems worldwide. They established that these losses corresponded to emissions of 949 million metric tons of carbon dioxide per year. The authors also estimated that adopting measures aimed at reducing such losses would lead to avoiding emissions in the range of 411 to 544 million metric tons of carbon dioxide annually. The second recent study, carried out by the IEA (2020), analyzed the losses from transmission and distribution systems at a global level and found a magnitude very similar to that detected by Surana and Jordaan (2019) in terms of emissions caused by the energy lost in 2018. In this report, the IEA (2020) estimated that reducing global losses to achieve efficiency levels of around 5% (versus current levels) would lead to a reduction in associated emissions by more than 400 Mt CO_2.

Surana and Jordaan (2019) show the magnitude of annual emissions derived from energy loss in transmission and distribution globally compared to other sectors. Figure 3.3.2 shows that emissions caused by electricity losses exceed those of other sectors such as the chemical industry, maritime transport, and the burning of residual gas from the hydrocarbon sector, among others.

The authors also note that very few countries include transmission and distribution losses in their national commitments to reduce greenhouse gas (GHG) emissions as part of the 2015 Paris Agreement. Only 32 countries mention grid efficiency, while 110 refer to some form of renewable energy.

Figure 3.4.1 Comparison of CO_2 emissions originating from electricity losses and other industrial sectors



Source: The Conversation, CC-BY-ND with data from Surana and Jordaan (2019)

Although CO_2 emissions from the electric sector in Latin America and the Caribbean are relatively low compared to other regions of the world, reducing electricity losses could be key for countries in the region to meet their Nationally Determined Contributions (NDCs). Furthermore, minimizing these losses can help reduce the positive relationship between economic growth and carbon emissions, a crucial step toward sustainable development. According to Balza *et al.* (2024), most middle and high-income regions have decoupled economic growth and carbon emissions over the past five decades. This suggests that once a certain income level is reached, these countries can experience growth while decreasing their carbon emissions. However, in LAC, there is a linear relationship between these variables, with emissions increasing as GDP per capita rises. Implementing a variety of policies, including strategies to reduce electricity losses in the region, could accelerate the transition to decouple economic growth from emissions.

More than money: Effects on electricity service quality

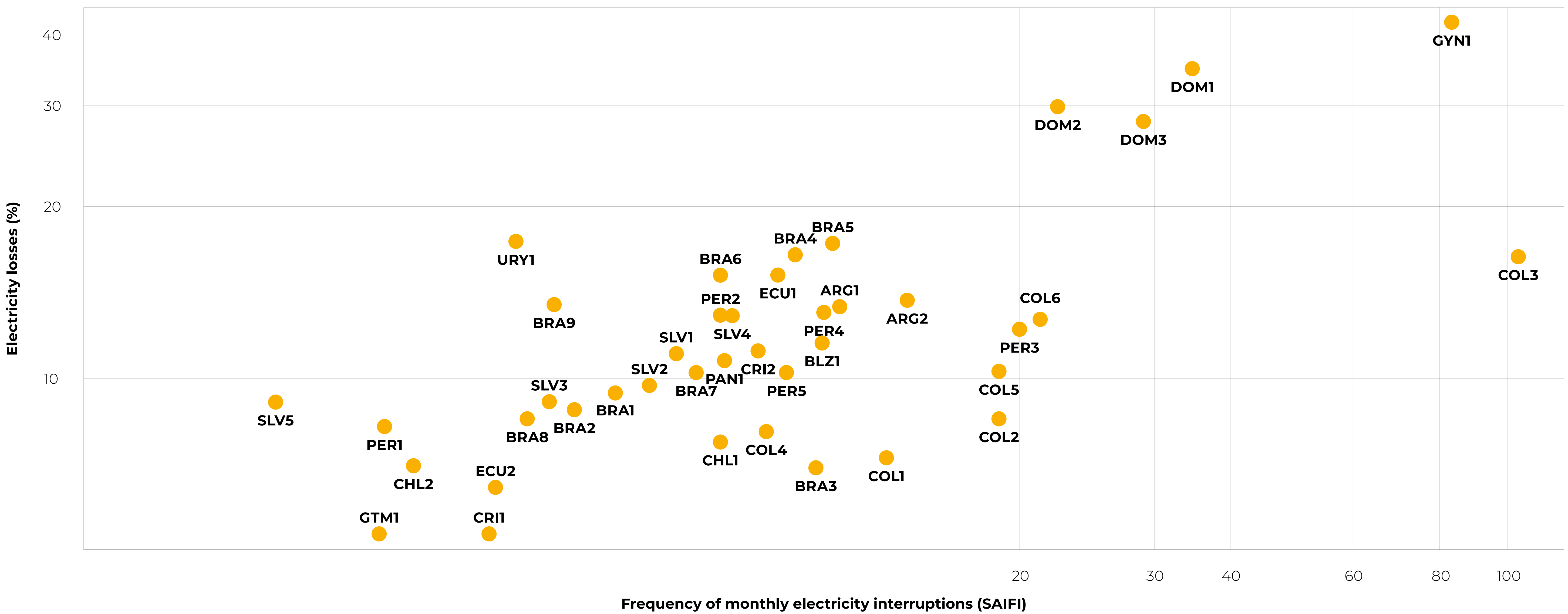
Quality of service is also closely related to electrical losses, particularly those of a commercial nature. Figure 3.10 shows a positive relationship between the magnitude of losses and the quality levels of electrical services in 41 electric utility companies from 15 countries in Latin America and the Caribbean. There are several possible explanations for the positive association between the two variables. For example, the existence of electrical losses may reflect deficiencies in the energy network that, in addition to losses, generate deficiencies in service continuity. These deficiencies may also arise from the saturation of the electric power system owing to overconsumption from unmetered consumption. The regular association between high losses and low service quality levels appears to be a worrying fact in energy distribution.

This association effectively means that electricity losses not only harm the utilities that receive no fees for the electricity they supply or the environment owing to excess emissions derived from the generation of compensatory electricity, but they also adversely affect the user via lower-quality electricity supply services.

Furthermore, it is potentially a vicious circle since the greater the problem of losses, the greater the expected deterioration in the financial sustainability and investment capacity of utility companies, further weakening their ability to control both variables. Therefore, there is a degree of complementarity between investments aimed at reducing losses and improving service quality levels, increasing both financial and social attractiveness.

Investments to reduce losses and improve service quality can generate synergies that increase financial and social attractiveness.

Figure 3.10 Electricity losses and quality of service in Latin America



Source: Jiménez (2021).

Note: The figure includes 41 electricity distribution companies in 15 Latin American countries. Abbreviations: DOM: Dominican Republic, NIC: Nicaragua, GYN, Guyana, COL: Colombia, PER: Peru, ARG: Argentina, BRA: Brazil, ECU: Ecuador, CRI: Costa Rica, CHL: Chile, GTM: Guatemala, SLV: Salvador, PAN: Panama. The information corresponds to the year 2015 and was compiled from available public sources (web pages of public utility companies, regulators, ministries). Both axes are plotted on logarithmic scales. The y-axis, "Electricity Losses (%)," represents the portion of electricity that goes unbilled by the public utility company, resulting in direct financial losses. On the x-axis, SAIFI stands for "System Average Interrupt Frequency Index."

3.4 Conclusions

The magnitude and trends of the electrical losses presented in this chapter suggest an alarming situation. The electricity losses in the transmission and distribution systems, exceeding 10%, amounted to approximately 120 TWh per year in the region, equivalent to the total solar and wind generation in 2019. The losses associated with these activities represent a significant proportion of the available energy, amounting to almost 17% in relative terms. These losses incur substantial environmental and financial costs that society must confront on a regular basis. The annual losses are equivalent to 5–6 million tons of CO2 emissions and a financial cost of approximately USD 14 billion, or 0.27% of the GDP in the region. Given the region's struggle to improve its sustainable infrastructure, the constant loss of resources over the past few decades represents a significant risk to the sustainability of the energy system.

The current situation, directly and indirectly, impacts various stakeholders in the electricity markets and society. It puts the financial sustainability of electric utility companies at risk by reducing their ability to make investments and improve the general infrastructure of the system. Lower revenues associated with unbilled energy negatively affect efforts to achieve better service quality standards or universal access to adequate modern energy services. On the other hand, users could be affected by the degradation in service quality and the increase in the service cost that would arise from the need to solve energy losses through increases in electricity prices. Even if the state covers the losses via subsidies or by the electric utility companies themselves, they would represent a high opportunity cost for society, as such resources could be used in investments with greater social (education or health) or economic profitability (renewable energy).

Although the availability of comparable aggregate information limits the characterization of the loss problem, it can be argued that the region's electrical losses are primarily non-technical. This type of loss implies greater complexity in its approach, which may exceed the framework of action or the range of control of electric utility companies. Thus, the need to focus on commercial losses under a comprehensive strategy emerges as an unavoidable aspect in the design of reduction and control measures.

One of the most concerning aspects of the current situation is that there has not been a substantial systematic improvement in loss levels over the past few decades. The lack of a significant reduction indicates the necessity for introducing more vigorous measures. The existing investment gap in the Latin American energy sector has amplified this urgency. If the current situation continues, it will be an unappealing scenario for drawing on the sector's required investment. Consequently, maintaining the status quo would significantly impede progress toward achieving universal access to sustainable energy and transitioning to more sustainable energy sources.

Chapter 4

Behind the scenes: what elements underlie electricity losses?

In the previous chapter we showed that there have been persistently high levels of electricity losses in the region during the last decades and that they can be grouped into technical and non-technical losses. This chapter aims to deepen the understanding of the fundamental elements that give rise to the aforementioned high levels of electricity losses. We also attempt to analyze the causes of their persistence over time.

International experience shows that there are several elements that can characterize the behavior of energy losses. Perhaps one of the most striking aspects is that they can include factors that go beyond the scope of action of electric utility companies, such as the quality of their management or their investment capacity. For example, situations of severe economic stress can affect the ability of households to pay for electrical services, which leads to an increase in the levels of non-technical losses.

This factor, along with other external elements, determines the business environment in the electricity markets and can significantly influence their performance. This chapter analyzes a set of elements in the context of the Latin American and the Caribbean (LAC) region. We specifically address the following: income, population density, economic crises, prices of inputs for energy generation. We also examine interrelated aspects that underlie company management, such as corporate governance, private participation, and regulatory frameworks.

Analysis of these factors suggests that they can effectively contribute to understanding the current situation in the region. Furthermore, the implicit message is that in cases of high energy losses, there is a more complex problem at play. Therefore, to tackle these challenges successfully, a comprehensive and well-reasoned approach is necessary.

4.1 Factors that influence electricity losses

Income

The close relationship between income level and electricity loss represents a stylized empirical fact. Two channels can be mentioned regarding the functioning of this relationship. First, the income level of a market (or country) can be related to the level of development of a country, availability of infrastructure and investment capacity, and institutional strength. The second channel, at the micro level, refers to the income level of the user base, which may reflect their degree of vulnerability and type of electrical connection (for example, the higher the income, the lower the incentives to connect to the grid illegally or avoid paying for electricity services received). Both channels are also linked, and at higher income levels, we expect lower losses either because the utility companies have adequate infrastructure and/or because the households have better economic conditions to access the electricity service.

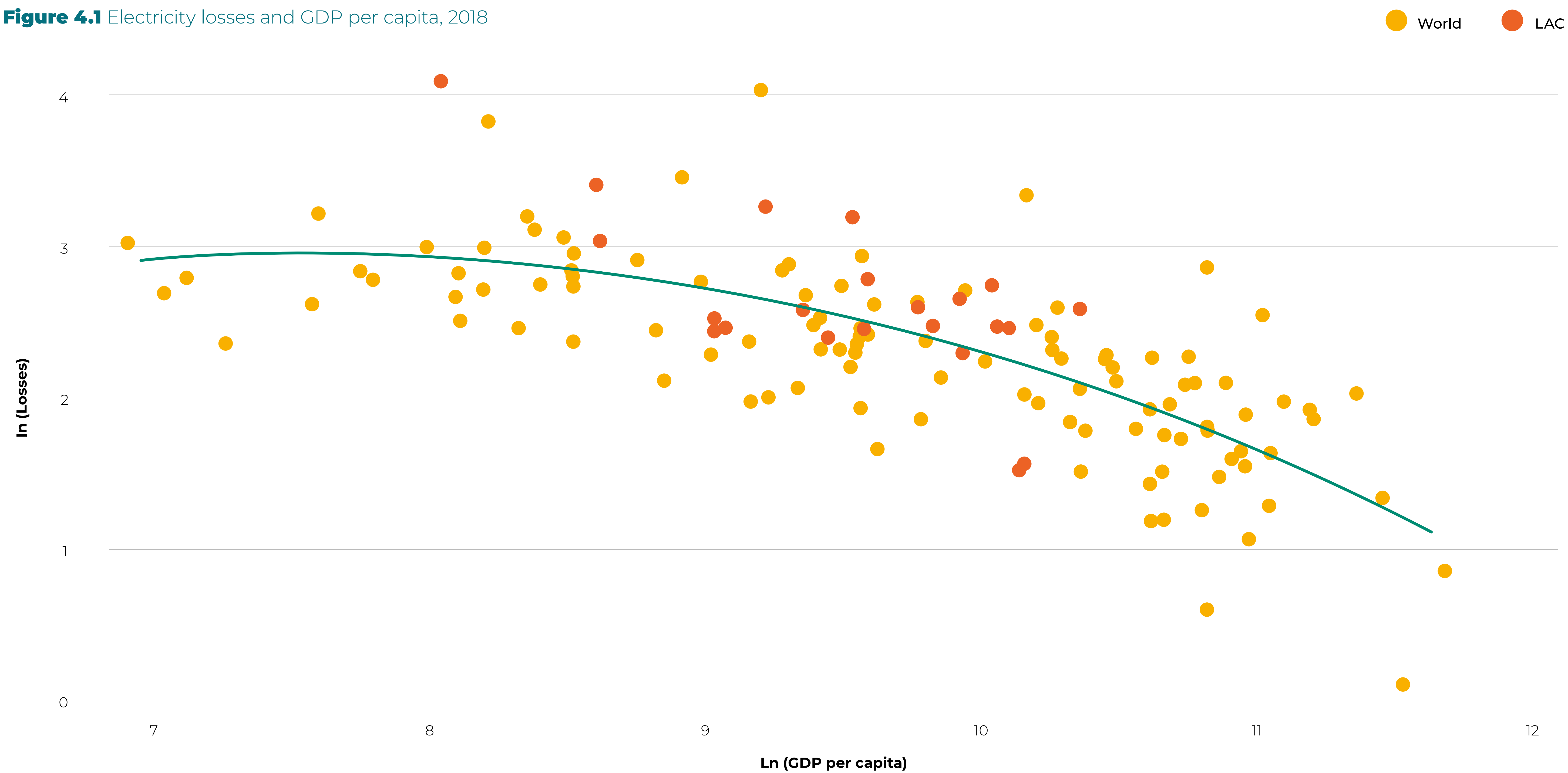
Figure 4.1 shows the distribution of loss levels versus the global GDP per capita. Here, an inverse relationship between income and losses can be observed for both the global sample of countries (non-LAC countries in black) and LAC countries (in blue). The plot also shows a high level of diversity in general; that is, for the minimum level of income, there are countries where losses can be high or relatively low. The following pages discuss other factors that may explain this diversity, at least partially. However, the inverse relationship between income and losses is consistent in a number of case studies (see, for example, Yurtseven (2015) and Gaur, V., and Gupta (2016)). On the other hand, there are certain cases in which high-income sectors and/or firms are sources of commercial losses, which can be large.[17] However, in aggregate terms, the pattern mentioned above emerges even in such situations.

Figure 4.1 also shows how many LAC countries are on the trend line, indicating that they present lower performance than the global average (from the sample). This is consistent with the analysis presented in Chapter 3 and suggests that in addition to income level, other relevant factors may influence the loss levels observed in this region. In stark contrast but consistent with the relationship discussed, Trinidad, Tobago, and Chile, with the highest incomes in the region, also show the lowest loss indicators.

We can also verify that electricity losses are concentrated in the most vulnerable groups at the micro-level. For example, based on national household surveys in Mexico, most potential households with non-technical losses are in the lowest income groups. See Box 4.1.

17. See, for example, reference to the case in Colombia in Section 2.2

Figure 4.1 Electricity losses and GDP per capita, 2018



Source: Prepared by the authors using as a reference 2018 data provided by the World Bank (World Development Indicators) and the International Energy Agency (IEA).

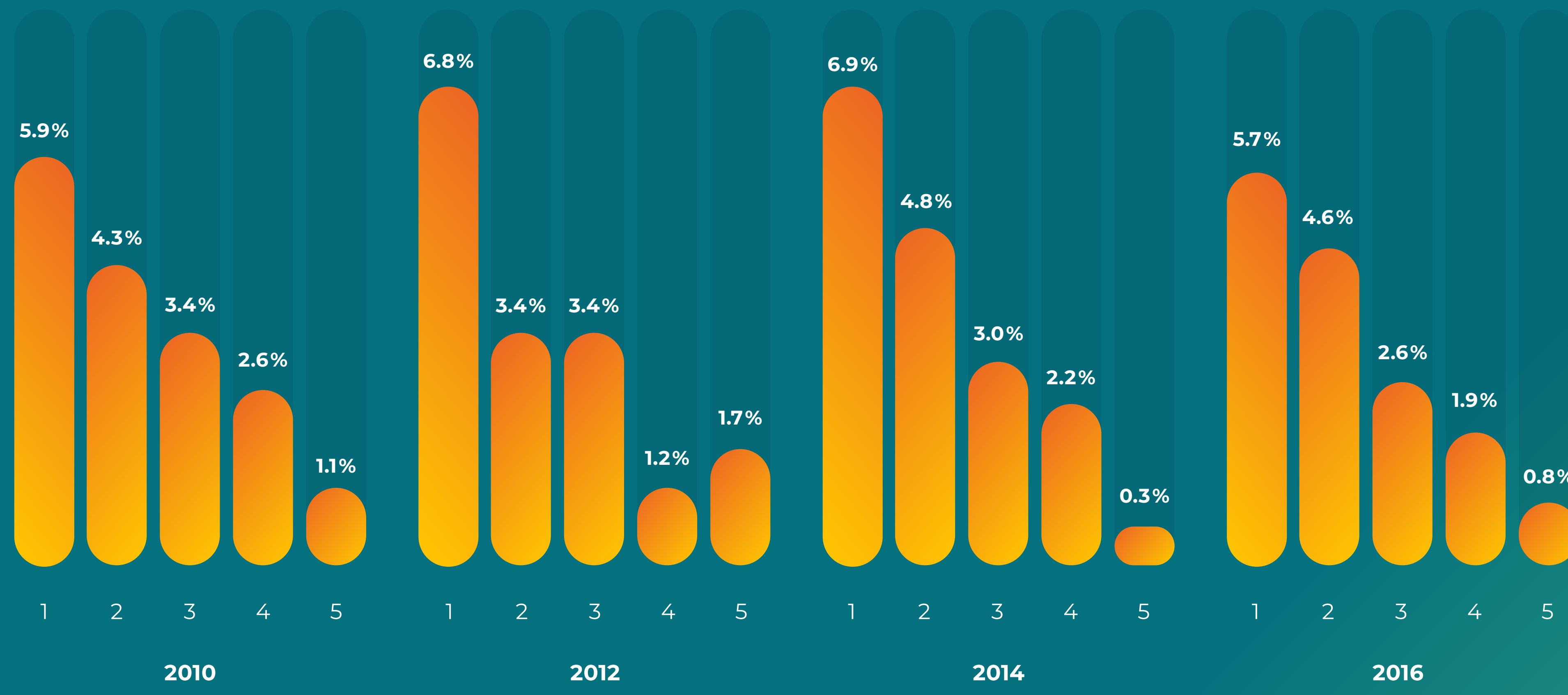
Box 4.1
Electricity losses and household income

The relationship between user income and electricity loss should emerge more clearly in the residential sector. This box examines where the largest number of residential users causing commercial losses are concentrated. Potential households in which commercial or non-technical losses occur can be identified based on national household surveys in Mexico. They are identified approximately by analyzing the possession of an electricity meter and the self-reporting of payments for electric services. These surveys also allow households to be grouped into their respective monetary income quintiles.

Figure 4.1.1 shows the percentage of households in which non-technical losses occurred between 2010 and 2016 by income quintile. The most significant occurrence is observed within the lowest socioeconomic strata. As in the review with aggregated country data, this is a marked and persistent pattern in the data, which has also been documented in other case studies (see, for example, Yurtseven, 2015).

Specifically, the figure shows that in the lowest income quintile (1), the percentage of users that would be a source of commercial losses lies around 6%–7%. This percentage gradually decreases as we move to the right of the income distribution. It is interesting to note that even the highest income groups may also be a source of electricity losses.

Figure 4.1.1 Non-technical electricity losses in Mexico's residential sector by income quintile, 2010–2016



Source: Prepared by the authors based on household income and expenditure surveys in Mexico for the years 2010–2016.
Note: The figure illustrates the percentage of households distributed by quintiles (1–5) of per capita household income. Quintile 1 represents those with the lowest income, while quintile 5 corresponds to households with the highest income.

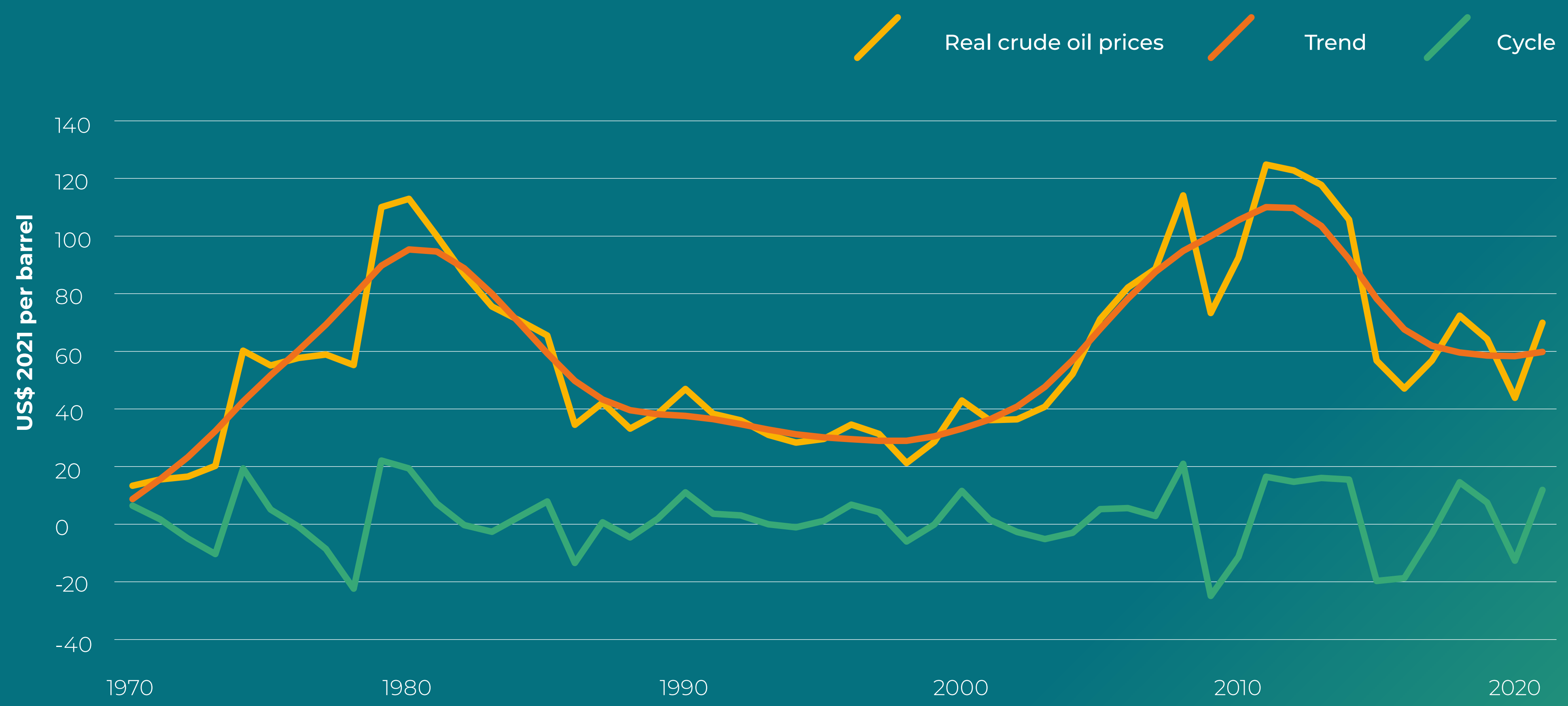
Box 4.2
International oil prices

When generation originates mainly from thermal systems, electricity prices become highly sensitive to variations in international oil prices. Peaks in the latter could substantially affect the willingness of end users to pay their bills, and this unpaid electricity is also considered here as an electrical loss and not a commercial or financial loss. This situation has occurred in oil-importing countries, such as Argentina, Chile, Jamaica, the Dominican Republic, and Nicaragua. Increases in electricity losses during 1973, 1979, 2002, and 2008 were attributed to high international oil prices. These periods coincide effectively with oil price levels that are above the general trend.

High oil prices do not just affect generation costs and, consequently, electricity rates. They also influence the total cost of the energy basket of residential and industrial users to the extent that they create incentives to reduce consumption or stop paying bills.

A related factor is the occurrence of weather events, such as droughts, in countries with significant hydroelectric energy generation. During these periods, systems tended to increase the use of fossil fuels (often more expensive and unstable) to compensate for any variation in the energy balance. Experiences in Brazil and Uruguay show the impact of the El Niño phenomenon that occurred in 1983 and 1997–1998, resulting in the reduced availability of hydroelectric energy and increased use of fossil fuels. Eventually, a considerable part of these additional costs, derived from increases in generation costs, was transferred to the bills of end users. This leads to an increase in nontechnical losses.

Figure 4.2.1 Trend and cycles of international oil prices



Source: Prepared by the authors based on data from BP Statistical Review of World Energy, June 2022.

Economic crises

A factor closely related to the income of users is the presence of economic crises at national and international levels. These situations help explain the variability in electricity loss trends by country. Given the heterogeneity in income distribution reflected in household consumption patterns, decreases in income resulting from economic crises could have asymmetric and multidimensional consequences. In the context of lower income, aggravated by rising energy costs – a common phenomenon in times of crisis – it could lead already vulnerable populations to energy poverty. In turn, this situation could aggravate their economic vulnerability until they reach extreme poverty levels. In such circumstances, one of the possible adaptation mechanisms for these households is the late payment of electricity bills. At the same time, there has been an increase in illegal connections and/or manipulation of meters to reduce their electricity bills.

These mechanisms could help explain the growth in electricity losses experienced by Argentina, Ecuador, Mexico, and Peru during their corresponding economic crises. Specifically, Argentina from 1999-2003, Ecuador from 1999-2000, Mexico in 1980, and Peru from 1990-1995. During these periods, these countries suffered from high inflation, high unemployment, significant reductions in real income, and drastic economic adjustments. These episodes illustrate how economic imbalances can exert a considerable influence on the management of the electricity sector.

In Argentina and Ecuador, the failure to pay bills was explicitly considered a loss of electricity. Specifically, in Argentina, during the crisis from 1999 to 2003, the government established that public services could not be suspended due to non-payment. Additionally, starting in 2002, it was determined that unbilled electricity would be counted as a loss that caused an increase in electricity losses. In the case of Ecuador, some public companies experienced a high rate of unpaid bills during 2002–2010. However, the government chose not to interrupt services and instead counted delinquencies as electricity losses.

A factor directly related to electricity losses is the decrease in users' ability to pay for the service.

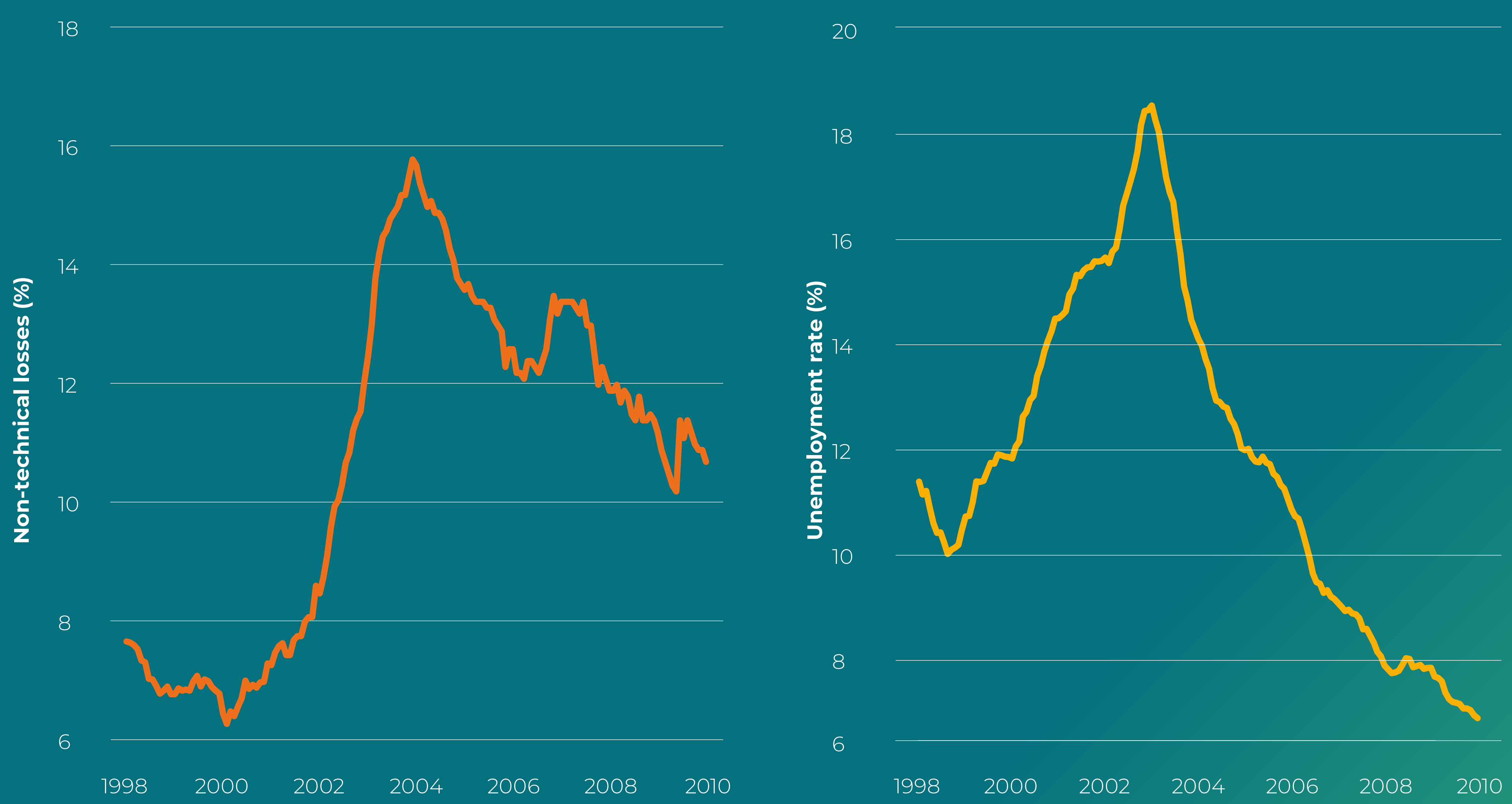
Box 4.3 Electricity losses and economic crises in Uruguay

The relationship between non-technical electricity losses and macroeconomic and social performance variables has been a subject of study in the empirical literature. As this chapter shows, economic crises are correlated with increased losses. Even electric utility companies attribute these increases in non-technical losses to these shocks. Such dynamics are illustrated, for example, in a study of non-technical losses in the city of Montevideo, Uruguay, the evolution of which was negatively correlated with unemployment levels. Figure 4.3.1 shows how non-technical electricity losses in the residential sector were affected by the increase in unemployment after the strong economic crisis the country went through, particularly between 2001 and 2003.

The other alarming implication of Figure 4.3.1 is that even when unemployment normalized and dropped below pre-crisis levels, electricity losses were only partially reversed after a decade.

However, the underlying mechanisms that give rise to this association are rather elusive. On the one hand, economic shocks harm the economy of households, which can force them to make irregular connections or alter meters. In addition, these actions are allowed by the electric utility companies and by the State as a countercyclical measure. This topic will be addressed in Chapters 7 and 8.

Figure 4.3.1 Evolution of non-technical losses and unemployment in Montevideo, Uruguay



Source: Adapted from López Cariboni (2019).

Population density

The geography of the service area and its population distribution are factors that underlie the economy of the user base. A high population density is generally associated with lower costs of grid installation and monitoring, control, and loss reduction programs. Therefore, areas with a high degree of urban development are often more attractive to electric utility companies in terms of profitability.

Figure 4.2 (A) presents the relationship between population density and transmission and distribution losses. Although the trend line has a negative slope, the marked variance of the sample makes it difficult to establish the relationship between the variables. For example, Costa Rica has a high population density among the countries examined and, at the same time, one of the lowest loss rates in the region. However, in Nicaragua, with a population density double that of Chile, there are losses of more than 20%, which is four times the losses in Chile.

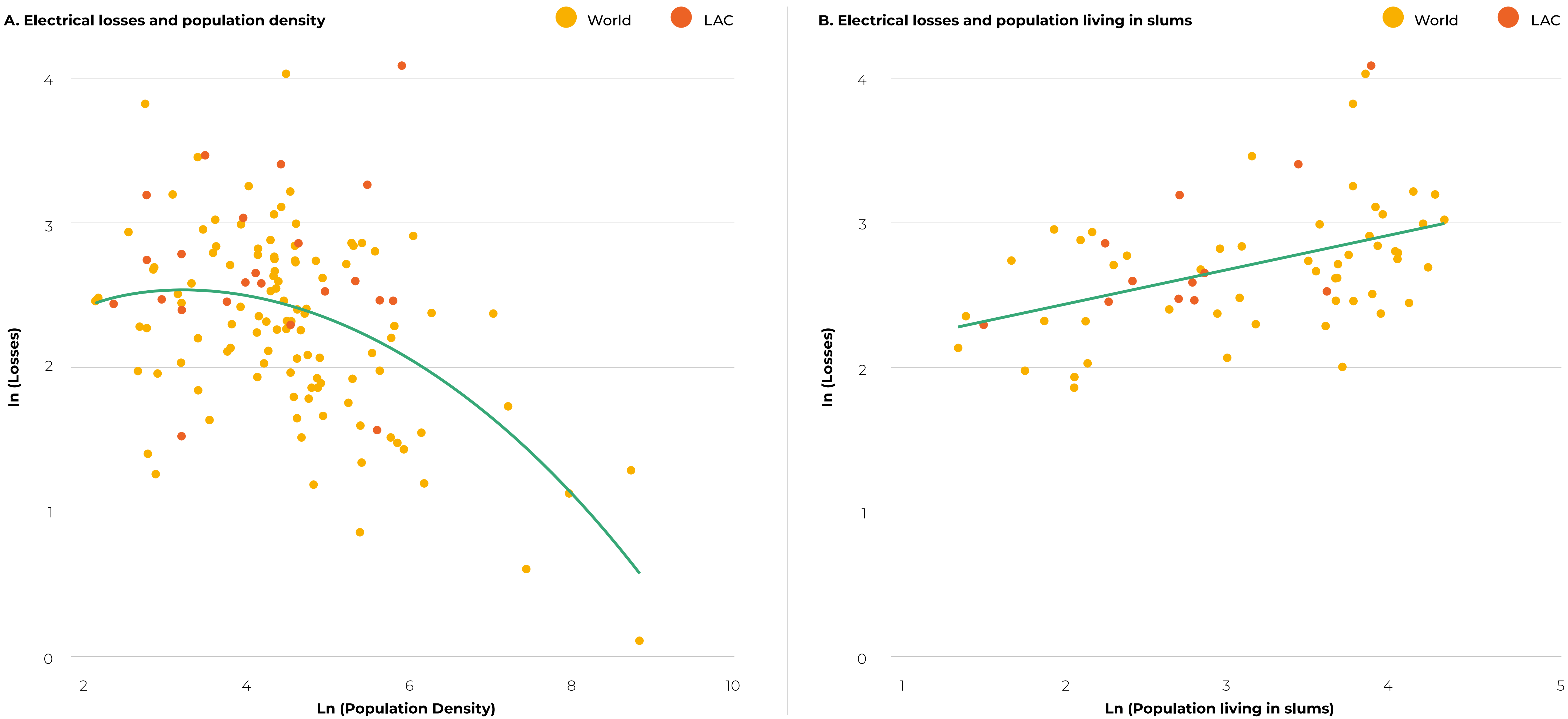
When looking only at LAC countries (orange dots), the relationship between electricity losses and population density is even more dispersed and counter-intuitive regarding what would be expected from a technical point of view (a negative correlation). In fact, because of the relatively high levels of population losses and densities in Venezuela, Nicaragua, Honduras, and Haiti, this association is diffuse, once again underscoring the particular nature of the challenges in the region.

The central hypothesis on why this situation occurs is related to the region's development and growth of urban centers. Specifically, in previous decades, urban growth has exceeded the capacity to invest in infrastructure in many cases. During this process, lower-income households tend to concentrate in settlements characterized by precarious infrastructure and irregular electrical connections. In short, although these areas have high population densities, they are equipped with poor infrastructure. This phenomenon can exacerbate nontechnical electricity losses and generate additional challenges in managing and distributing electrical energy in these areas.

The persistence of this precarious infrastructure in different areas of LAC cities represents a visible multi-sectoral challenge that goes beyond the problems of electrical service affordability. For example, many of these areas suffer from the absence of property titles, which hinders the normalization of connections in these populations.

Figure 4.2 (B) shows the relationship between loss levels and the percentage of each country's population living in areas classified as slums (according to the World Bank classification). It shows how the quality of the infrastructure in our cities can partially explain the high levels of losses despite the relatively high levels of population density.

Figure 4.2 Losses and population distribution, 2018



Source: Prepared by the authors using as a reference 2018 data provided by the World Bank (World Development Indicators) and the International Energy Agency (IEA).
Note: The figure shows on the y-axis the logarithm of transmission and distribution losses, while the x-axis measures the logarithm of population density.

Private participation

Attracting private participation has been a central element in the reform of several electricity markets in the region. Private stakeholders have represented an indispensable source of investment resources and a channel for technology transfer and good management practices in electric utility companies. The injection of private capital makes it possible, for example, to improve and expand transmission and distribution lines, which contributes to reducing both technical and non-technical losses. Regarding distribution and commercialization, the presence of private stakeholders reinforces incentives to improve monitoring, which in turn promotes the legal connection of new users.

Adequate regulation and supervision have represented a fundamental pillar to achieving positive impacts on electric electricity system users, as we shall see below. Support from the public sector is an essential condition for creating a stable and transparent environment that facilitates the deployment of private investments in the energy field.

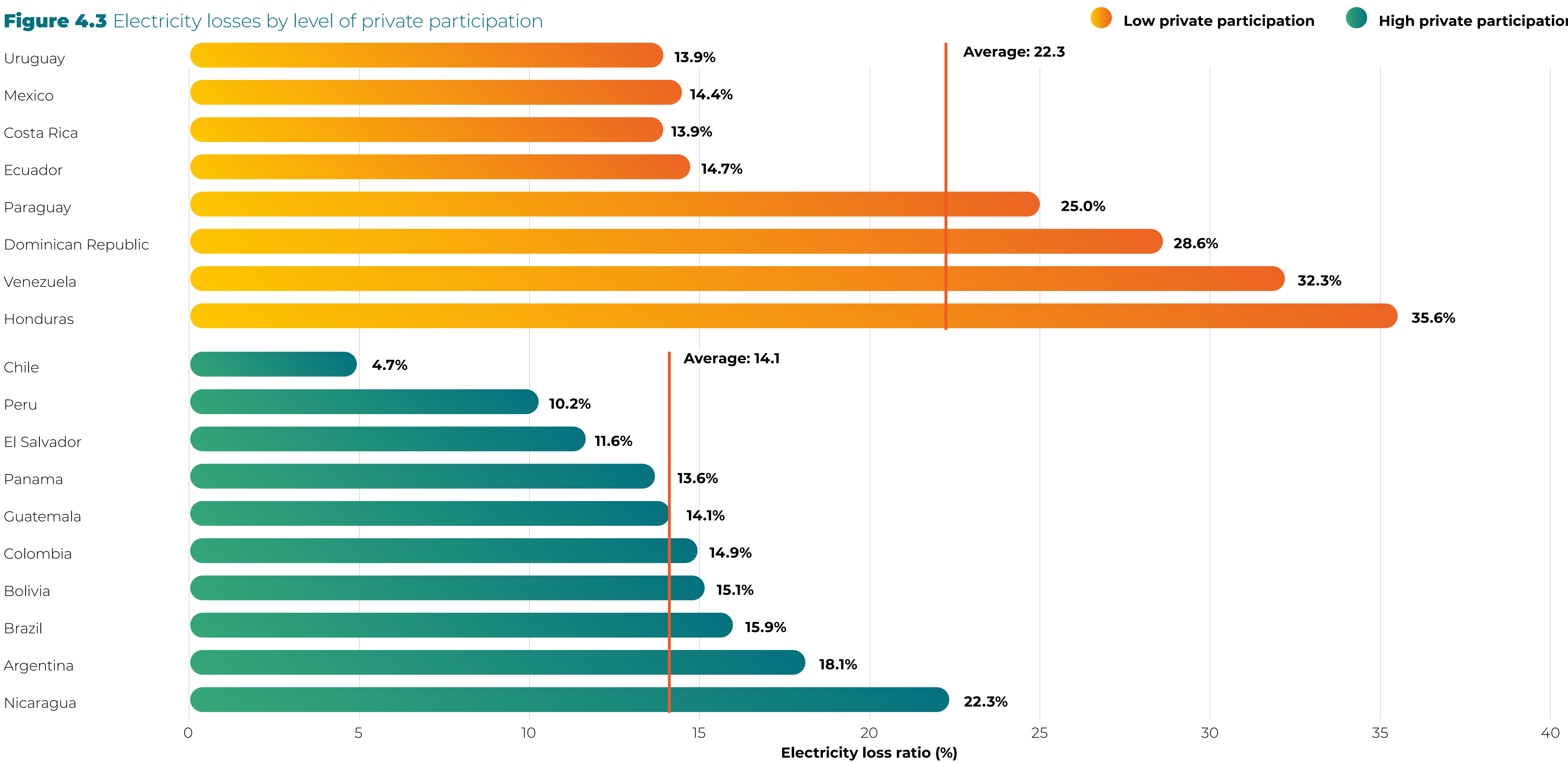
The history of these reform processes shows cases where private participation processes have led to systematic and substantial improvements in the levels of electricity losses. For example, at different points in time, countries such as Argentina (1997), Chile (1987), Panama (1998), and Peru (1995) recorded significant reductions in electricity losses after their respective privatization periods. These are examples of intensive private participation that, in turn, involves changes in governance in the distribution and commercialization sectors.[18]

Figure 4.3 shows the average electricity losses over the last five years by a group of countries and by the degree of private investment in the electricity transmission and distribution sectors. Concerning the latter, they are grouped into two categories: low, non-existent, and high. Although a significant level of diversity is observed between countries, those with greater private investment in the electricity sector tend to exhibit lower average losses (approximately 14 %). By contrast, in countries with limited or no private participation, electricity losses reach approximately 22%.

Private participation in the sector contributes to closing investment gaps, resulting in the optimization of electrical infrastructure and a reduction in losses.

18. In the case of Chile, the Electrical Portability Law establishes the division of distribution and commercializing functions, as well as the concept of an information manager that allows them to be separated.

Figure 4.3 Electricity losses by level of private participation



Source: Prepared by the authors based on IEA data and official public sources.

Note: Electricity losses are the 5-year moving average. Private participation corresponds to the year 2015, extracted from Balza, Jimenez, Macedo and Mercado (2020). In Nicaragua, distribution companies were absorbed by the State in 2020.

Regulatory frameworks

Regardless of the ownership structure of electric utility companies, adequate institutional and regulatory frameworks are essential for achieving better efficiency in the management of electric services. Stability and transparency in these frameworks are among the most important signals that governments can send to agents in the sector: consumers, operators, and investors.

The implications of reducing the electricity losses are direct. On the one hand, without adequate game rules, it will be extremely difficult to finance and implement the necessary investments to improve the transmission and distribution infrastructure to reduce and control losses. For example, regulatory risk can discourage the entry of investors and operators into the sector and increase financing costs.

On the other hand, regulations provide frameworks that encourage companies in the sector to prioritize loss reduction and facilitate the adoption of new technologies. For example, one of the effective measures adopted in the region is incentives that promote the transparent and predetermined formation of electricity rates. These mechanisms only partially establish the recovery of losses via rate adjustment, thus facilitating companies to reduce electricity losses.[19] By contrast, the absence of well-defined and transparent mechanisms can give rise to price distortions with high regressive impacts, leading to poor performance of utility companies. Experience shows that this tool, traditionally associated with privatized markets, can operate perfectly in markets with state participation (for example, in the cases of Peru and Chile). Particularly in systems with high public participation, incentives via rates can constitute a strategy for reducing electricity losses with zero fiscal impact.

This regulation also makes it possible to deploy technologies that facilitate the monitoring and controlling of losses. Typically, regulations establish goals and/or guidelines that favor technological adoption, such as implementing smart electricity consumption measurement systems to combat losses. For example, the regulatory framework that operates in the European Union[20] seeks to achieve 80% coverage of consumers with smart meters. As its coverage expands, the accuracy of the consumption measurements is expected to improve significantly, leading to a decrease in the proportion of users who steal electricity.

Institutional and regulatory measures

Specific measures or strategies have been adopted in some countries to reduce electricity losses as part of the framework governing the electricity sector. For example, in the case of Ecuador in 2006, the electricity law was reformulated to include penalties for illegal connections, and a plan was initiated to reduce losses. For instance, Paraguay took steps in the mid-2000s to strengthen its loss reduction efforts. These measures were grounded in the belief that without robust institutions that ensure compliance with regulations to deter electricity theft, overcoming this issue will be even more difficult. This lack of compulsory nature reduces the incentive to comply with the rules and, as a result, encourages informality in the payment of electricity bills.

In the case of Ecuador, measures were implemented that made the obligation to comply with the rules credible, and the institutional organization executed them effectively. The reduction of losses from 24.5% to 18.7% between the years 2006 and 2010 can be attributed to the implementation of various measures that were ca-

19. In general terms, several countries have implemented systems based on the definition of loss reduction goals, which incentivize outstanding performance of electricity sector operators and penalize unsatisfactory performance. To validate these schemes, regulatory authorities agree on a maximum limit of losses that can be covered through the prices paid by the end consumer. These types of mechanisms have been imposed so that system operators (distribution) engage in adequate management and avoid having to cover losses that exceed the maximum limit set by the regulator.
20. European Parliament Directive 2009/72 of 13 July 2009 concerning common rules for the internal European market in electricity (2003/54/EC).

rried out simultaneously. It is important to mention that Ecuador's case also involved other institutional measures and an extensive investment plan, which are further discussed in Chapter 5.. In this experience, the relevance of institutional measures and their sustainability over time can be observed in the fact that losses in the country have continued to drop, being on the order of 14–15% at the beginning of this decade.

Electric Utility Company Management

Companies may have different management practices and experiences that enable them to face the problem of electricity loss with different degrees of effectiveness and efficiency. Although this element is difficult to characterize and is linked to a company's ownership structure and institutional framework, in this subsection, we will describe some elements of company management that may be relevant when addressing the losses that they face. In short, companies' governance structure can facilitate their internal capacity to address the problem of losses.

Corporate governance

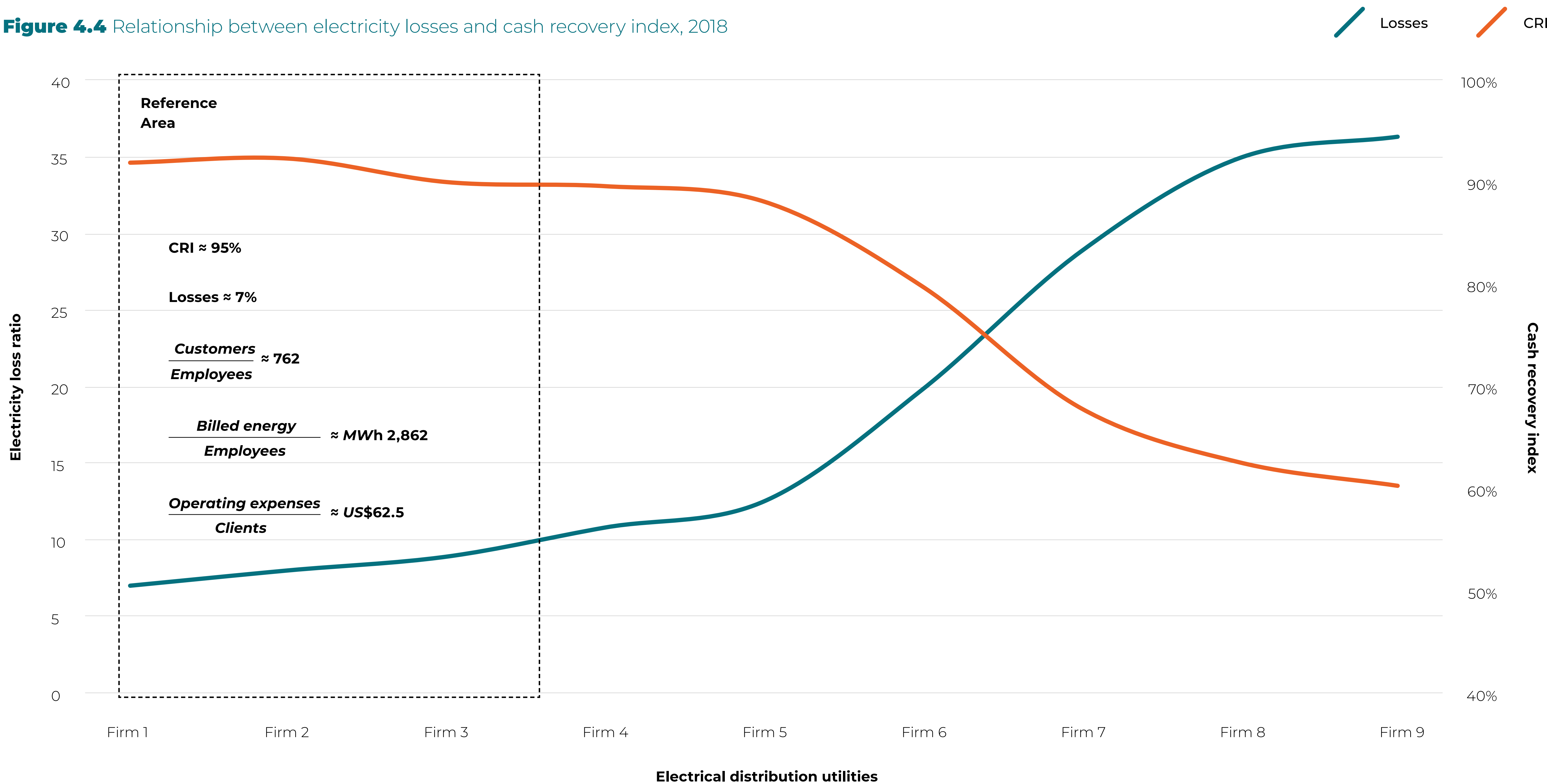
Appropriate corporate governance allows for strategic decisions, monitoring, and incentivizing efficient performance at the operational level. Good corporate governance practices are characterized by making it easier for the company (or its managers) to make decisions independently of its majority shareholders. By contrast, weak management autonomy can lead to suboptimal operational and financial results. In other words, at the corporate governance level, electric utility companies need space for action to implement their business priorities and strategies, evaluate the results, and change their business strategy if adequate results are not achieved. In this sense, good corporate governance practices constitute a key element of operational sustainability in the sector.

Financial, operational, and commercial management

Broadly speaking, the integral parts of the management structure generally specialize in financial, operational, and commercial areas. Corporate-level monitoring of a company's health from a business perspective is one of the most relevant functions of these areas. This process involves formulating goals in line with long-term objectives, as well as periodic monitoring through financial and operational indicators that make it possible to evaluate the implementation and effectiveness of actions aimed at optimizing the company's performance, including measures to reduce electricity losses.

It is challenging to establish comparable measures between companies regarding the effectiveness of their internal control policies and schemes because they respond to the specific contexts in which they operate. Likewise, as previously mentioned, there are factors outside the company that can lead to high losses and bad debts, regardless of the quality of the company's management. However, management practices play an important role in managing this problem. This association is evident in Figure 4.4, which shows how the cash recovery rate (orange curve) behaves versus the total electricity losses (blue curve) in a sample of nine utility companies. Companies with high levels of bad debt also exhibit high levels of electricity loss. This situation directly impacts the distribution company's income and has an inverse effect on the cash recovery rate.

Figure 4.4 Relationship between electricity losses and cash recovery index, 2018



Source: Prepared by the authors based on information collected by the IDB Infrastructure Department.

Distribution companies that successfully minimize electricity losses achieve higher revenue per unit generated, resulting in higher rates of return on assets and superior gross yields.

The level of losses is also associated with financial profitability indicators and service reliability of distribution companies. We reviewed the relationship between company-level losses and financial profitability indicators (ROA and EBITDA)[21] and reliability (SAIDI and SAIFI)[22] based on a small sample of 22 electricity distribution entities operating in 11 countries in the region.

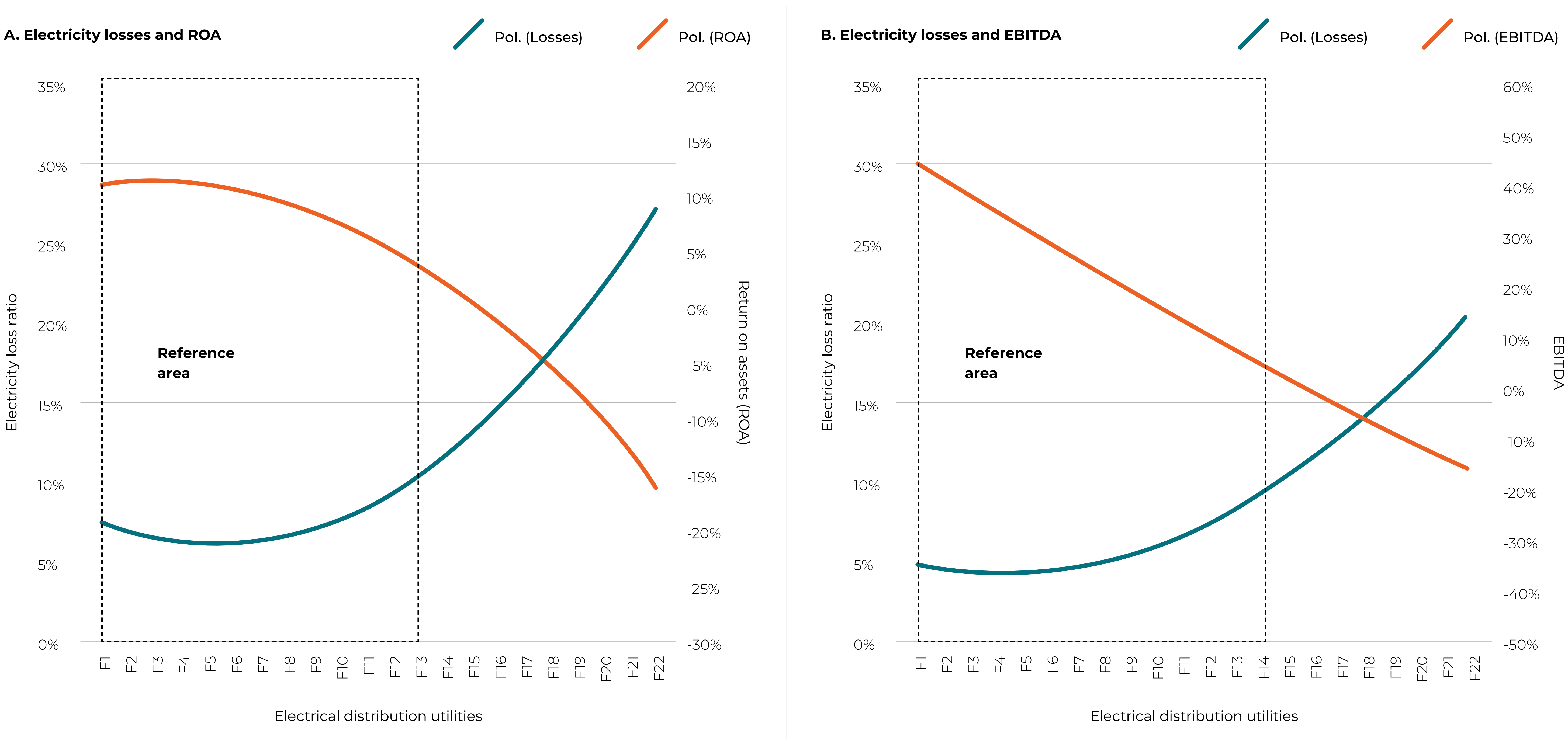
Figure 4.5 shows the inverse relationship between the electricity losses and profitability indicators. Distribution companies with lower electricity losses show a higher income per unit generated. As a result, their rates of return on assets are better, and their gross returns are higher.

It can be inferred that there is a correlation between the rise in electricity losses and a decline in the reliability indicators of the electric electricity system. As depicted in Figure 4.6, this relationship is evident in the positive trend between the polynomial that approximates the level of losses and the corresponding values of SAIDI and SAIFI. The relationship is proportional and indicates that the distribution companies with the worst reliability indicators are also those with the highest levels of losses. This relationship can be explained by the fact that electric utility companies that incur lower losses have more income to invest in infrastructure and operational practices that allow them to increase the reliability of their service.

Therefore, the patterns described above suggest that companies with levels of electricity losses below 10% (as a general reference) show adequate performance in indicators of operational efficiency, quality of service provided, and profitability. The "reference areas" indicated in the charts suggest ranges for indicators consistent with loss levels considered not excessively high in this document.

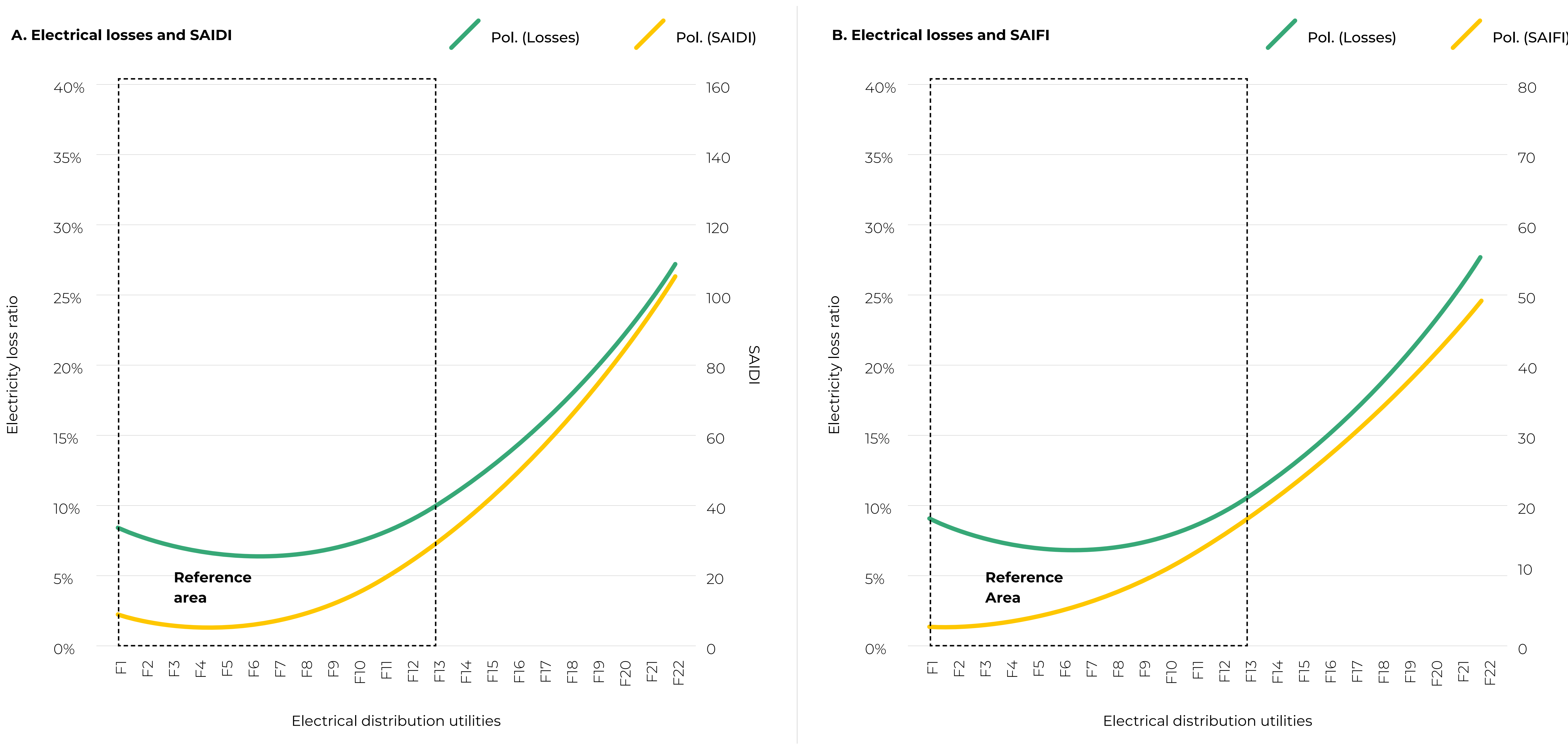
21. Return on assets (ROA) is a measure of a company's profitability in relation to its total assets. Earnings before interest, taxes, depreciation and amortization (EBITDA) makes it possible to evaluate a company's performance regardless of its financing method.
22. The SAIDI (System Average Interruption Duration Index) measures the average duration of interruptions in electricity supply suffered by a user. And the SAIFI (System Average Interruption Frequency Index) reflects the number of times the user is affected by an interruption.

Figure 4.5 Relationship between losses and profitability, 2018



Source: Prepared by the authors based on information collected by the IDB Infrastructure Department.
Note: The lines depicted represent Order 2 polynomial trend lines.

Figure 4.6 Relationship between losses and quality of electrical service, 2018



Source: Prepared by the authors based on information collected by the IDB Infrastructure Department.

Nota: The lines depicted represent Order 2 polynomial trend lines.

4.2 Relative contribution

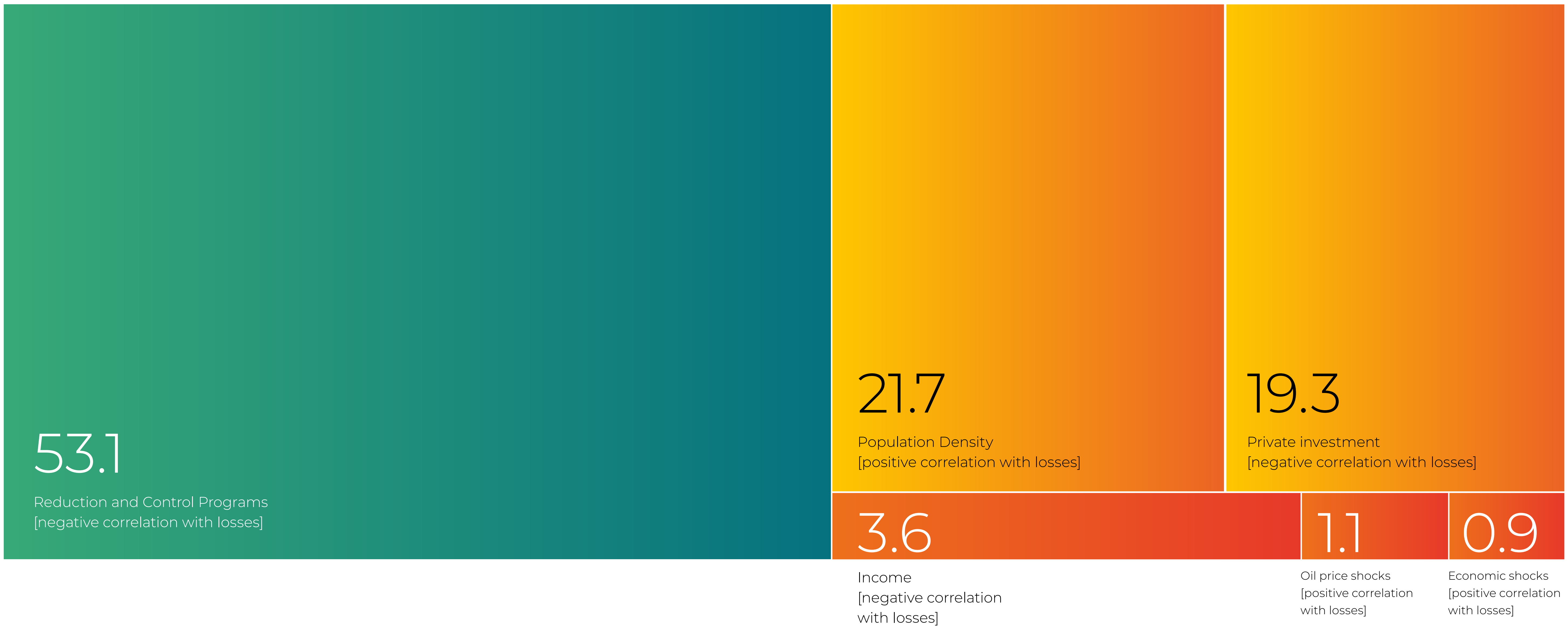
How do the factors described above explain the variability observed in the electricity losses of various countries in recent decades? Addressing this question presents a significant challenge, and the subsection partially captures the complex relationships that can be established. This is largely due to the fact that the factors mentioned above are deeply interconnected, making it difficult to distinguish the specific influence of each one.[23] For example, the quality of a company's management is closely associated with the historical strength of the country's institutional framework and, potentially, with its ownership structure.

The region has undergone significant transformations over the last five decades, making integrating them for quantitative analysis challenging. Nonetheless, patterns that enable a partial understanding of their impact on the levels and assessment of losses can be discerned. Among them, we can highlight the processes of reform of electric electricity systems, the notable growth of urban centers or population density, changes in income levels, and economic shocks.

Figure 4.7 shows the relative contribution of these factors to the observed variance in electricity losses over the last four decades. Although this figure represents only a partial view in terms of the number of factors that have affected loss levels and their interrelationships, it is interesting to note that programs and measures aimed explicitly at reducing losses have played a central role. These measures are expected to reflect a significant part of the observed variation, as they are typically implemented in scenarios with high levels of losses. However, it is important to note that these results may be overestimated for two reasons. First, it is possible that the programs used in this exercise mainly included successful and widely applied programs. On the other hand, some of these programs involve direct support for public utility companies at the distribution level for greater investment and to improve their practices. Therefore, these programs could reflect complementary measures at the level of electric utility companies, which are not explicitly captured in the underlying model.

23. The availability of quantitative analyzes that can clearly delineate the impact of loss reduction policies and measures is notoriously limited. This fact highlights a relevant gap in contemporary economic literature, presenting a valuable opportunity for future research in this field.

Figure 4.7 Relative contribution of key factors in the variability recorded in electricity losses



Source: Authors' elaboration based on data from the International Energy Agency (IEA), International Monetary Fund (IMF), Penn World Tables, and World Bank Development Indicators.
Nota: An econometric analysis was carried out using a regression model with panel data to quantify the adjusted correlations between electricity losses and each of the previously defined exogenous factors. This exercise includes data from 22 LAC countries between 1971 and 2010. The figure shows the proportion of the variance that is explained by the regressors (electricity losses as a function of population density, income, private investment, oil price shocks, economic shocks and loss reduction programs) for 18 LAC countries. The data set was built with information from the International Energy Agency (IEA), International Monetary Fund (IMF), Penn World Tables and World Bank Development Indicators.

The population density reflects a large part of the variability in losses. As previously mentioned, in the case of developing countries, and specifically in the Latin America and Caribbean (LAC) region, it has been observed that the greatest increases in population density have largely explained positive variations in the levels of losses. This can be primarily attributed to the period under consideration, which spanned from 1971 to 2016. During this time, most Latin American cities experienced rapid growth that exceeded their planning and investment capacities. In recent years, population density has stabilized, so it is likely that in the future, it will play a less important role in explaining variations in loss levels.

Private investments have also played a notable role in reducing losses. However, it would only have limited scope by itself. Successful private participation requires a strong and transparent institutional framework that establishes consistent incentives over time, which is difficult to separate in this analysis; part of this contribution must be attributed to it. Under this indispensable condition (appropriate regulatory framework), the channels through which private participation has played a favorable role are diverse. On the one hand, its presence suggests the mobilization of new fundamental investments to improve and expand infrastructure. On the other hand, private participation can favor innovation in management and the greater use of new technologies for managing losses.

Highly correlated factors, such as per capita income and economic and oil price shocks, appear to play less significant roles. Regarding income, it should be noted that the analysis in Figure 4.7 is based on a group of 18 LAC countries, which results in less pronounced variations in income compared to a larger sample of countries at the global level, which would have greater diversity in terms of income. However, it was observed that the countries exhibited substantial variations in income over the decades under analysis, which were associated with reductions in the levels of losses. Two channels can be distinguished through which higher levels of income would lead to lower levels of losses: (i) greater payment capacity of consumers and (ii) greater investment capacity (see the previous section). Regardless of this negative correlation, a latent question for policymakers is whether loss levels have responded adequately (i.e., have not decreased) despite the economic growth observed in recent decades. Certainly, although economic growth can be beneficial in reducing the problem of electricity losses, it may not be sufficient, and we have to identify the barriers that limit progress in this matter.

In turn, shocks to oil and economic prices, which mainly affect energy prices or the income of the population, thereby restricting the affordability of the service, can have (and have had) effects in various contexts that are by no means insignificant. Given the transitory nature of these events, their effects tend to reduce in the long term. Although these shocks may be temporary, their consequences may be systemic or prolonged. One element that concerns policymakers is how to decouple the occurrence of such shocks from the permanent changes in the performance of the electric electricity system.

4.3 Conclusions

The goal of reducing electrical loss levels in the region has been difficult to achieve over the past decades. This chapter aims to provide a comprehensive understanding of the complexity of this issue by offering an aggregated perspective on several factors that impact the progression of electricity losses at the national level. These factors range from macroeconomic variables to aspects related to company management. Although the analysis of these factors was only partial, the main message is that they are closely interconnected and considerably impact loss levels.

According to the review presented in this chapter, electricity losses have been observed to exhibit a procyclical relationship with economic cycles. In other words, macroeconomic, regulatory, and external risks can manifest as increases in energy loss. Additionally, a positive correlation was detected between loss levels and vulnerable areas of the population. As a result, we can deduce that high levels of electricity loss also reflect the existing development disparities in the region.

Thus, there are opportunities to mitigate these risks. For example, during positive economic growth and windfall profits, reserve funds can be established to finance actions that mitigate the impact of economic shocks. In periods of economic hardship, government responses can be coordinated promptly to ensure access to quality infrastructure services while mitigating potential negative impacts on businesses in the sector. The fundamental condition to facilitate the adequate operation of the electricity sector lies in its institutional solidity and stability. Building on these foundations, companies in the sector can plan beyond economic cycles and achieve consistent results in reducing and controlling electricity losses over time. In the absence of solid institutions, transitory shocks exacerbate long-term losses.

One implication of the procyclicality of electricity losses is that periods of economic prosperity and low energy prices can be used to implement loss-reduction programs. These programs must be aimed at benefiting the target population, and investment in social programs should be coordinated in parallel to implement these initiatives. Adequate communication of the benefits of these programs (such as quality improvements, positive environmental aspects, and greater security in public areas) can also help gain support for these types of policies and programs.

Our analysis suggests that specific loss reduction programs can be highly effective when integrated into broader plans and policies. These successful programs are usually linked to institutional measures (e.g., management independence of companies and transparent and consistent rate formation schemes that encourage adequate management). Furthermore, considerable long-term investment efforts are essential.

Recent decades have shown that private participation can play a crucial role in attracting investment and promoting innovation within the framework of solid institutional structures. Electricity systems with greater private participation tend to present higher levels of efficiency and, on average, lower levels of electricity loss. Therefore, these significant benefits must be considered, especially in the context of high fiscal pressure and substantial gaps in infrastructure investment. Again, it should be emphasized that this pattern is not automatic and that performance in the sector always depends on the institutional environment.

Chapter 5

Experiences in reduction and control of electrical losses[24]

24. Chapter prepared jointly by Raul Jimenez, Rigoberto Ariel Yepez-Garcia, and David Matías.

This chapter addresses the following question: What characteristics separate effective loss-reduction experiences? To this end, we focused our case review on the Latin American and Caribbean (LAC) regions. To guarantee the robustness of the analysis, we decided not to discriminate between the periods considered. By doing so, we aim to identify longstanding customs that are universally applicable and relevant to our current contexts. This review finds that, despite the severity of the problem of losses in the region, several experiences show concrete plans and actions that have been successful.

At a very general level, some guidelines can be distinguished that have enabled these measures, such as a clear identification and appreciation of their favorable cost-benefit balance, political will, and consistency regarding their implementation, among others. At a more granular level, given the diversity of contexts in these countries as well as the different restrictions that apply to companies in the sector, it is not easy to identify specific measures or actions that can be generalized between companies in different countries. At this level, loss-reduction programs must be carefully designed and implemented to suit the client.

This chapter addresses common practices from different experiences that have been observed to achieve a sustained level of loss reduction. However, it is worth emphasizing the vast diversity of experiences at the regional level, only a few of which are reflected in this chapter.

This section presents an overview of some common factors that characterize compelling experiences, while subsequent sections explore these experiences and the increasing use of technological innovations to address the problem of electricity loss cost-effectively.

5.1 Common areas

Companies in the sector are bound by different institutional frameworks, financing (and funding) restrictions, and the particularities of their respective areas. These factors outline, among others, the actions or measures that can be implemented, the intensity with which they can be executed, and their respective effectiveness. Therefore, it is neither easy nor possible to identify a set of specific actions that can be generalized to different companies. However, it is possible to characterize some of the experiences in the region and find some commonalities. This section first summarizes the most general characteristics of these experiences and then mentions some common practices they share. At a more general level, the following are some complementary and interrelated characteristics that can generate important synergies when applied together:

1. **Political support and consistency.** Temporal consistency and institutional transparency appear to be central aspects of loss-reduction experiences. Political support is key to implementing necessary reforms and guaranteeing sufficient investment flows. Such support needs to be institutionalized through transparent regulations that materialize commitment to an efficient and sustainable electricity market. It is worth highlighting that consistency does not mean rigidity and that policy goals and regulatory/supervision frameworks can (and should) be adapted to market and contextual challenges. This is particularly relevant in the energy sector, which

has experienced notable technological changes in the last decade and can be significantly influenced by external events (e.g., climate change, economic crises, and pandemics). At the same time, the government and electric utility companies must be aligned and committed to the reform, as well as its associated costs, goals, and compliance deadlines..

2. **Alignment of incentives.** The structuring of an incentive system enables companies to effectively achieve their loss reduction goals and sustain them in the long term. It is a challenge with effects that range from the regulatory sphere to business management. The financial sustainability of companies must be cleared of external interference, for which adequate pricing mechanisms must be established to recover costs. For example, these conditions are essential for establishing a rating system based on the performance of electric utility companies. In turn, national goals must be reasonable within the sector's capabilities and consistent with company goals under adequate enforcement mechanisms.

3. **Long-term strategies.** The establishment of targets, plans (including evaluation) for regulatory reforms, and investment processes requires the setting of credible deadlines. These deadlines need to reflect the investment capacities, financing, and implementation of such investments, as well as the expected (and necessary) growth of these capacities.

4. **Cost-benefit analysis.** With well-established incentives and a long-term vision, the definition of goals, assignment (identification) of investment (needs), and prioritization of measures and projects to be implemented should be based on a cost-benefit logic to proceed with those investments that return greater financial and social profits. Such an analysis should evaluate loss-reduction programs' potential net social and systemic benefits. For example, they are associated with improvements in the quality of service, less dependence on subsidies to cover financial gaps in unpaid energy, and greater efficiencies in transportation and energy consumption, among others.

5. **Holistic perspective.** As with any infrastructure project, numerous implementation risks exist. One way to address this is through a holistic perspective in the design and execution of loss reduction programs, which can include everything from intersectoral coordination to social awareness programs in the areas of intervention.

6. **Incorporation of new technologies.** The integration of new technologies is a necessary condition for the electricity sector, but it also offers new opportunities to reduce and control loss levels in a cost-effective manner (e.g., the use of pre-paid meters or artificial intelligence to detect potential situations of theft or technical inefficiencies).

7. **Accountability.** There must be an adequate distribution of responsibilities for the different commitments required in a loss reduction program. At the same time, organizations or authorities in charge of these responsibilities need to have execution capacity.

8 **Monitoring effectiveness and efficiency.** Implementing a system to evaluate and monitor the effectiveness and efficiency of achieving loss reduction goals should constitute an organic part of long-term programs. These monitoring and evaluation systems can also play a central role in assigning responsibilities among different stakeholders, warning about potential design or implementation weaknesses, and deploying improvements in a timely manner..

9 **Communication of benefits.** It is essential to communicate the benefits and profits of loss reduction, as well as economic and financial profits and social, environmental, and sectoral benefits. For example, loss reduction programs will not only improve the financial health of companies but will also improve service quality while generating tax and energy savings. Communicating these benefits to end customers and relevant government actors and the electric power system can strengthen consensus and political-social support for such programs..

As shown in Chapters 3 and 4, electricity losses have not been continuously reduced in the region and remain a widespread problem. A probable explanation is that the prevalence of the problem is mainly due to marked intersectoral and institutional complexity that makes it difficult to implement effective measures to reduce and control electricity losses sustainably.

In this sense, the aspects above are extremely complicated to implement, and particularly in countries that face pronounced losses, may require a unit specifically assigned to coordinate energy loss reduction programs/policies. The real challenge lies in the details, and in that sense, the management elements for successful design and implementation are essential. One of the basic elements is to solidify political support and institutional harmonization involving various areas (finance, presidency, energy, etc.) and guarantee a sustainable flow of investments for a prolonged period.

Given that electric utility companies that experience significant losses frequently encounter obstacles in accessing market financing, it is evident that there is a considerable opportunity for development financing to be utilized. In this context, multilateral development banks (MDBs) can play an important role not only as sources of long-term financing but also as catalysts for shared objectives between sectors and as communicators of best practices.

To offer more specific examples, Table 5.1 presents a set of general measures implemented in various loss-reduction programs. Many of the crosscutting measures mentioned seek to assign responsibilities to the corresponding stakeholders and create incentives for the system to be self-sustaining. These measures can be considered the basis for improvements and expansion in physical infrastructure to translate into improvements in efficiency and service quality and reduction of losses.

It is also important to highlight that implementing a specific type of crosscutting measure differs in its application from those mentioned above owing to the diversity of institutional environments and the contexts of the service areas of each utility company. Implementers must have the flexibility and degrees of freedom to design and implement loss reduction policies/programs while maintaining the principles of transparency and accountability.

Table 5.1 General measures in loss reduction programs

Areas	Measures
1 Political support, alignment with the government, and awareness campaigns	Strengthening the role of government authorities in addressing the problem of electricity losses.
	Establishing reporting mechanisms from public companies to the competent authorities at different levels of government.
	Establishing a policy framework regulated by an independent entity (Colombia).
	Social and marketing programs to promote awareness among users about the value of electricity.
2 Creating partnerships with local authorities (police and judiciary) and conducting awareness campaigns	Establishing clear penalties for energy theft and an administrative and/or legal process to institute sanctions (Uruguay).
	Complaint reporting system (Chile: online energy theft reporting system).
	Awareness campaigns on energy theft.
3 Legal and regulatory frameworks	Granting independence and/or autonomy to the regulator.
	Conferring independence and/or governance autonomy to the electric utility company.
	Gradually eliminating fiscal transfers to electric utility companies.
	Establishing regulations for regulating electricity losses.
	Issuing laws for coercive and criminal proceedings for non-payment or illicit use of public services.
	Creating tax incentives and remuneration proportional to capital for companies with better efficiency indicators.
4 Priority investments in technology for loss monitoring	Increasing the deployment of technological tools such as AMI (Automated Metering Infrastructure) measurement as well as supervision and database management systems (Dominican Republic: started with priority segments, i.e., users with consumption greater than 400 kWh).
	Using business intelligence tools and data analysis platforms to control losses (Brazil: Anti-Theft Project of the Ampla company).
5 Social participation and equity considerations	Designing a dialogue mechanism with the community that has the support of non-governmental organizations (NGOs).
	Setting special rates for low-income users to recover production costs.
	Identifying the main incentives for achieving client regularization.
	Considering a prepaid system (Colombia: Prepaid Electricity Program).
	Implementing user debt normalization programs.
6 Commercial management and Corporate governance of Utility Companies	Developing long-term plans with short and medium-term goals.
	Implementing business information systems and prioritizing data measurement.
	Carrying out comprehensive management of measurement, billing, collection, disconnection/reconnection, and meter inspection.
	Improving the service to the end user.
	Expanding the customer service point.
	Communicating punitive measures to discourage energy theft.
	Continuous on-site monitoring for irregular connections, damaged or tampered meters, and network condition.
7 Supervision	Creating an independent control body (regulator).
	Developing a long-term loss reduction plan that binds all stakeholders in the sector.
	Supervising the implementation of the reduction plan (by the regulator).
	Creating loss control indicators, supervision schemes, and fines.
	Establishing an independent unit dedicated to the management and monitoring of losses of distribution companies.

Source: Prepared by the authors.

Investment areas

Investment programs are typically related to strengthening infrastructure and generally aim to build and/or improve networks to make them less vulnerable to theft and/or transport energy more efficiently.

It is also important to distinguish between the measures to address transmission losses and those applied to distribution losses. Unlike distribution losses, transmission losses are mainly technical and can be even more challenging to reduce, especially when they are already close to healthy levels of efficiency. In relative terms, losses in transmission networks are lower than distribution losses because they tend to occur in higher-voltage networks, which are less susceptible to technical losses and theft. In contrast, transmission lines tend to establish (macro) measurement mechanisms that facilitate control. In this sense, technical losses can be reduced using more efficient transformers or operating with higher voltages in distribution networks, among other options. Using a higher voltage in the distribution network partially explains why losses tend to be relatively low in countries where this practice is common.

The following section analyzes the measures adopted in Chile, Ecuador, Mexico, Paraguay, and Uruguay, which have substantially contributed to reducing losses over the last 20 years. Additionally, the Energy Division of the Inter-American Development Bank[25] has made a parallel effort to produce a toolbox (Power Utility Toolkit) for the better performance of regional distribution subsector companies. This is useful for such companies, as it compiles the best practices of a diverse group of distribution companies in 17 LAC countries.

International experience shows that the most favorable distribution companies employ a holistic approach to loss reduction. Table 5.2 presents the effective measures implemented in the region's countries that have been transformed into best practices aimed at enhancing corporate performance by applying these approaches.

Although previously mentioned, it is worth reiterating that a shared fundamental principle during the creation of Table 5.2 was the consistent promotion of investment processes that foster long-term political harmony and dedication. This is crucial, as discussed in Chapter 4, because significant reductions in losses do not usually materialize in the near term (less than five years). Therefore, it is necessary to politically validate and endorse an adequate institutional environment that allows for a consistent investment process and execution of control and loss reduction measures under realistic expectations and goals.

25. For more information on the set of distribution companies analyzed and the best practices that emerged from said analysis, see Bonzi Teixeira *et al.* (2021a).

Table 5.2 Selected experiences in loss reduction

Areas	Measures
1 **Technical losses**	Construction of new trunk networks.
	Installation of meters, circuit controllers and totalizers on primary branches.
	Installation of (anti-theft) meters and protection boxes.
	Installation of intelligent measurement equipment.
	Reorganization of the medium voltage network and improvement of existing areas.
	Creation of new networks.
	Customer regularization (extension of sub transmission and distribution networks).
2 **Non-technical losses**	Classification of electricity theft as a crime (e.g., Brazil).
	Payment solutions: Half is used to erase the previous debt and the other half to pay current electricity consumption so that the debt does not grow.
	Extension of distribution networks and service standardization.
	Simultaneous measurement in substations. These provide reference lines to individual readings per user.
3 **General control and monitoring practices**	Georeferenced databases.
	Management systems (computer programs). Today, the collection, control and analysis of data flows have become essential for designing successful business strategies.[26]

Source: Prepared by the authors.

26. This not only allows for us to analyze and implement timely measures to overcome deficiencies, but also to detect business opportunities for electric utility companies.

Incentives matter – performance-based rates

One of the examples of regulatory measures that have yielded visibly positive results in terms of achieving loss reduction targets within predetermined deadlines is the establishment of performance-based tariffs. Incentives through the formation of electricity tariffs have contributed to generating a distribution of responsibilities leading to improved performance of actors in the electricity markets. This mechanism consists of the regulator setting a pricing system whereby the electricity distribution and/or transmission company can only charge the end user a percentage of the electrical losses. Under this scheme, the company must assume the differential cost of the losses that occur in the distribution, which motivates them to adopt measures for their reduction in order to achieve a positive financial balance.

The goal is to directly incentivize companies to limit or reduce the volume of energy losses by charging them the cost of the additional energy they need to cover these losses. Incentives need to have appropriate objectives and deadlines, as otherwise, they could pose difficulties for the sustainability of electric companies. For example, in defining goals and the deadlines to achieve them, it is appropriate to understand how the system's losses are composed (differentiating between technical and non-technical losses) and the severity levels of their components. Likewise, the company's financial condition and its concession area's socioeconomic characteristics should be considered. As mentioned, technical and non-technical losses typically require different treatments and may involve different investment magnitudes. The electric company's financial situation and the coverage area's profitability are determinants for setting realistic goals and deadlines. For example, These various peculiarities will be reflected in multi-year tariff plans.

Below, we present some cases of countries implementing this type of incentive, specifically Colombia, Panama, and Peru. In general, the electricity prices in these countries are comprised of the following components:

1. Costs associated with the user, regardless of their demand for power and energy.
2. Standard distribution losses in power and energy.
3. Standard investment, maintenance, and operation costs associated with distribution per unit of power supplied.

It can be said that the regulator estimates reference prices based on a company with efficient operation. Efficiency standards depend on many factors, including the composition of the country's energy mix, its generation technologies, the geography of the transmission and distribution system, and contextual considerations of the country or service area. Under this pricing scheme, lower levels of electricity loss (recognized or standard) can result in lower electricity rates. Additionally, loss levels that exceed the margins allowed by regulation (for recognition in rates) negatively affect the net income of electric utility companies.

As shown in Figure 5.1, the implementation of rate reforms (which incorporate the recognition of losses in the pricing of performance-based rates) coincides with the beginning of a decreasing trend in electricity losses in all three countries. This would result in positive effects on the financial sustainability of companies, efficiency of the system, well-being of households through improvements in the quality of service, and, potentially, a general reduction in electricity rates.

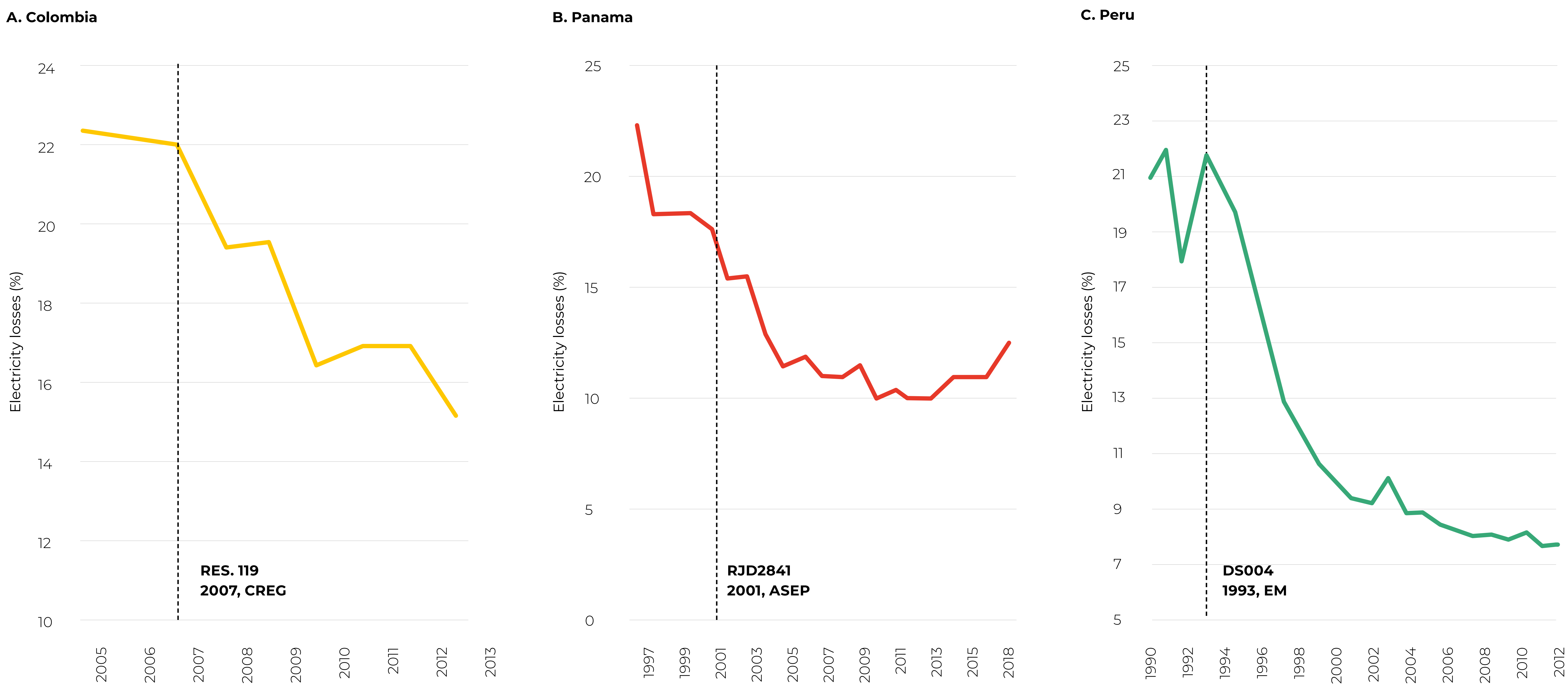
It is worth mentioning that price improvements to end users are not always feasible. In developing countries with significant investment needs, rates should also incorporate the amortization of such investments. This situation can neutralize the potential savings obtained through loss reduction. However, while rates are subject to regulation, they also have room to rebalance their different components. In other words, the savings from loss reduction can be directed toward financing other components while providing electricity services.

The potential advantages of reform may prove substantial. For instance, the Peruvian regulatory agency conducted a regulatory impact evaluation of the electricity rate reform discussed in these pages and found that the lower electricity rates had a positive impact on the family budget (due to reductions in losses) in the order of USD 252 million (at 2015 values). Box 5.1 summarizes this case study.

This description of the common elements underscores the importance of examining the lessons learned from the countries in the region. Furthermore, it emphasizes the need to draw on the experiences gained from other parts of the world, particularly those that have proven successful through incentive-based regulation. Annex 2 investigates the application of an incentive-based approach to mitigate and minimize electricity loss across multiple European nations. Through this endeavor, various experiences have emerged, encompassing, among other things, the regulatory classification of distribution and transmission losses. Although the differences are due to the particularities of each context, the lessons learned from each of these countries can help build knowledge regarding the continuous improvement of regulatory frameworks in LAC.

The economic benefits derived from the reduction in electricity losses represent a source of capital that can be reinvested in other critical areas of the electrical service provision process.

Figure 5.1 Rate reforms and evolution of electricity losses in distribution



Source: Authors' elaboration based on data from IEA, the Energy and Gas Regulatory Commission (CREG) of Colombia, the National Public Services Authority (ASEP) of Panama, the Ministry of Energy and Mines of Peru (EM), and the Supervisory Body of Investment in Energy and Mining of Peru.

Box 5.1
Ex-post evaluation of the impact of energy loss regulation in Peru

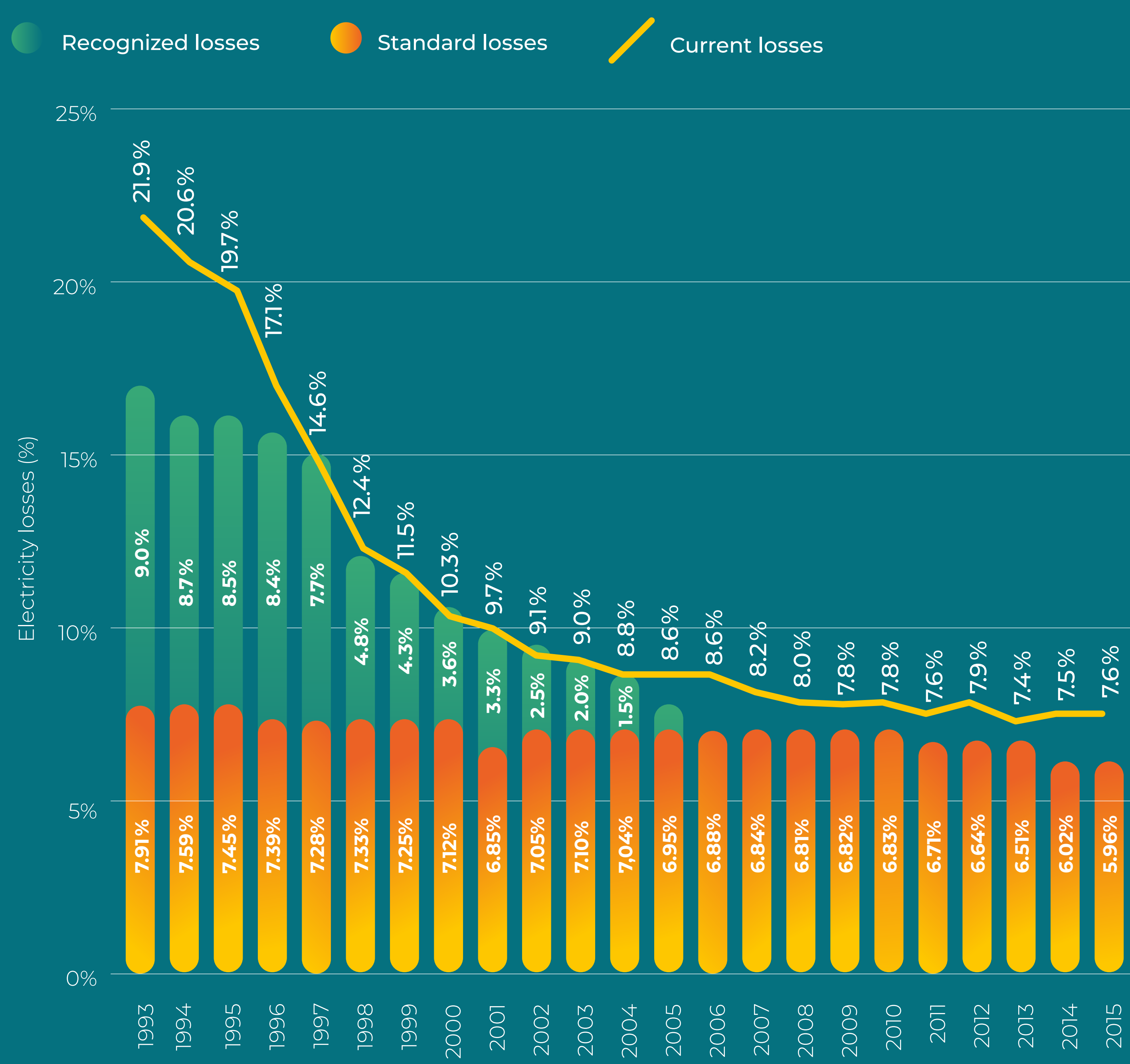
At the beginning of the 1990s, Peru reported a loss level of approximately 20%. As part of the electricity sector reform process, it was possible to reduce losses to 7%–8% (2015–2019). In 2017, the regulatory body analyzed regulation's impact on reducing electricity losses and rates. The study showed that companies in the sector achieved a decrease in associated costs, which, in turn, reduced electricity rates and thus improved the well-being of households.

Figure 5.1.1 summarizes the implementation of the incentive scheme and its effects on the loss levels. The regulation established the concept of standard losses, which includes a level of technical losses and another level of commercial losses, as well as their incorporation into rates. Technical losses were determined to guarantee a minimum level of quality, whereas commercial losses should not exceed 50% of technical losses. Recognizing the sector's problems, at the beginning of the nineties, it was decided that during the first years of implementation of the regulation, an additional percentage of losses would be admitted in the rates, which would decrease until they disappeared.

As shown in Figure 5.1.1, the percentage of energy losses in the distribution at the national level dropped from 21.9% in 1993 to 7.6% in 2015. The total percentage of losses incorporated into the rates equals the sum of the standard losses (orange bar) and recognized losses (green bar). Since 2005, only standard losses have been included in distribution rates. Furthermore, this percentage of standard losses has continued to decrease, which has favored a reduction in electricity rates.

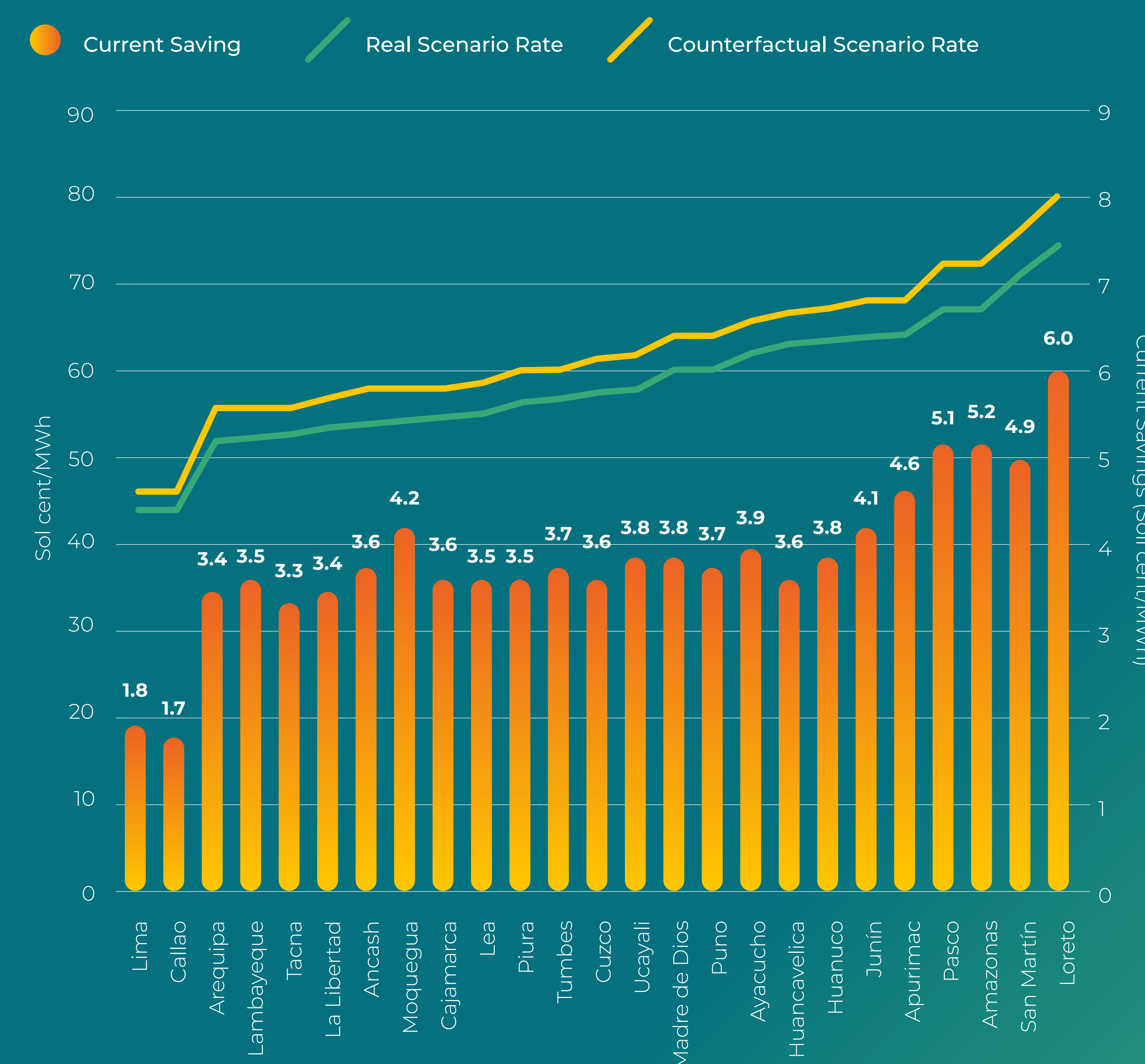
The ex-post evaluation of this regulation of electricity losses focused on its impact on the well-being of residential users through rate reduction, which resulted from reducing losses that could be recognized in the rates. The study estimated a counterfactual rate that assumed that the percentage of losses incorporated remained constant at the level corresponding to 2001. Figure 5.1.2 shows the electricity rates paid by residential users in each scenario for 2015. For example, the rate of users in the Lima region in a real scenario was approximately S/. 0.51 per kWh, while in the counterfactual scenario, it was S/. 0.55 per kWh, which generated an estimated savings of S/. 0.04 per kWh consumed.

Figure 5.1.1 Evolution of energy losses in Peru



Source: Adapted from Vásquez *et al.* (2017).

Figure 5.1.2 Electricity rates for residential users by scenarios, 2015

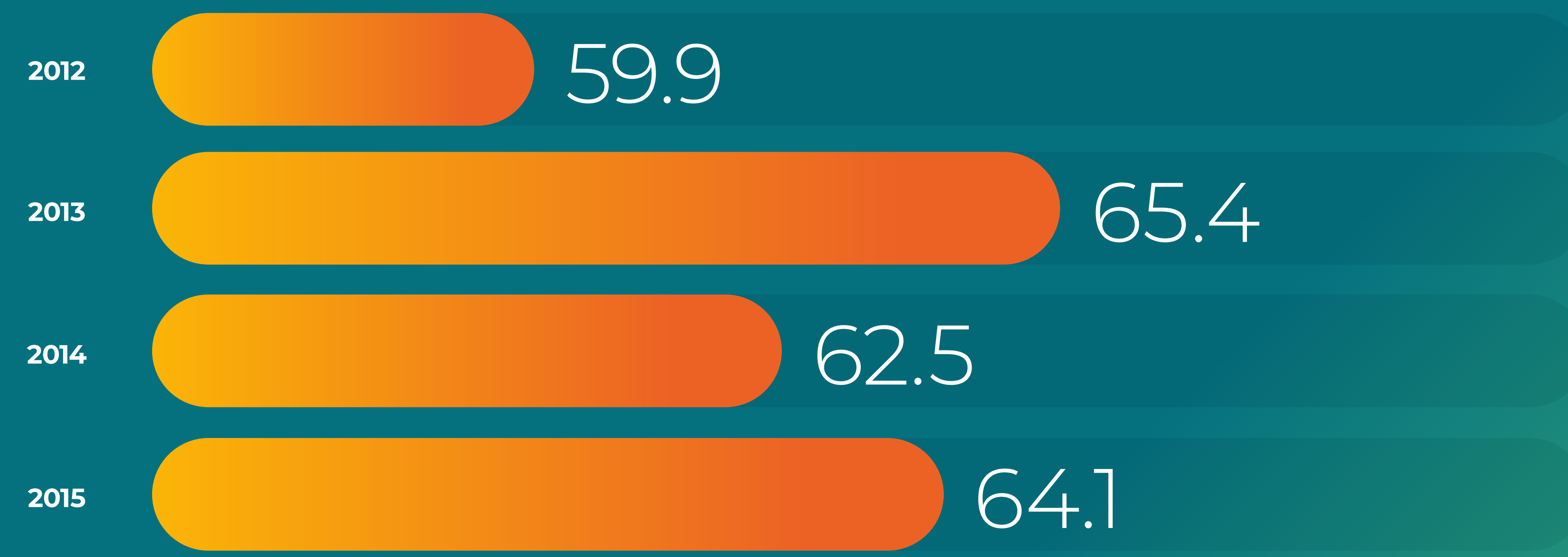


Source: Adapted from Vásquez *et al.* (2017).

The reduction of losses in the electrical sector can be attributed to the institutional reforms undertaken in the early 90s, including incentive-based regulatory schemes. This regulatory framework has promoted cost efficiency in companies, leading to more affordable electricity rates and contributing to the economic well-being of households.

The advantages of reduced losses are quantified by comparing the current situation (real scenario) of consumers' well-being with that of a hypothetical situation in which the losses considered in the rate have not decreased (counterfactual scenario). The regulator's study used equivalent variation as a measure of well-being, which is interpreted as the amount of money consumers are willing to pay for the regulator to maintain the loss reduction policy. As shown in figure 5.1.3, between 2012 and 2015, the regulatory incentive scheme allowed energy losses to decrease, which had a positive impact on family budgets due to lower electricity rates. In 2015, the total estimated benefit was USD 252 million.

Figure 5.1.3 Economic impact of reducing energy losses, 2012–2015 (Millions of 2015 USD)



Source: Adapted from Vásquez *et al.* (2017).

5.2 Case studies

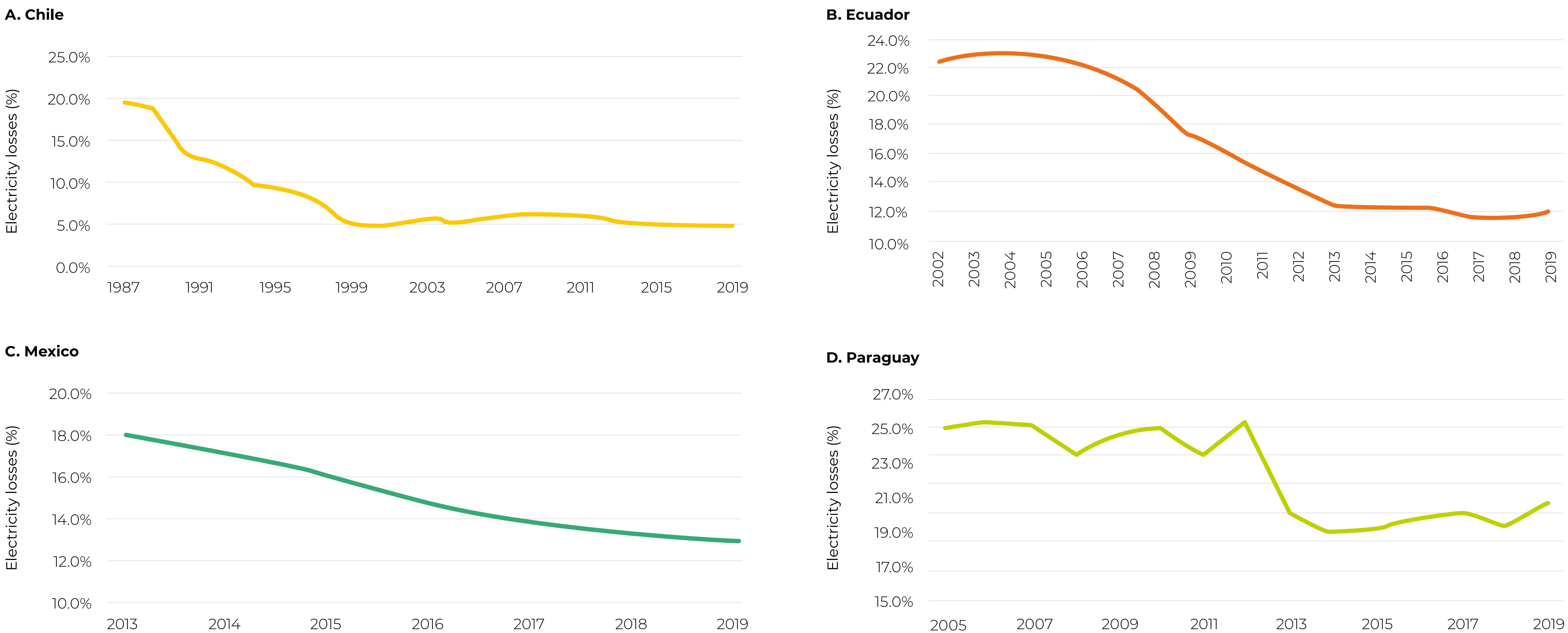
The case studies were chosen based on a balance between accessibility of the information and outstanding results in loss reduction. Data availability is a considerable obstacle in documenting experiences. Additionally, it should be noted that significant and persistent decreases in losses appear to be the exception rather than the norm in the region. With these factors in mind, we proceeded to identify those experiences that exhibited consistent reductions in electricity loss. Subsequently, an analysis was conducted on those that registered a significant drop in their levels of distribution losses, as long as the reduction was related to any of the previously mentioned measures.

This subsection presents the experiences of Chile, Ecuador, Mexico, and Paraguay. The objective is to report the specific measures implemented by electric utility companies to reduce electricity losses. Decreasing trends in losses as a result of the implemented measures are shown in Figure 5.2. It should be noted that the corporate management actions identified are closely interrelated and may not reflect all the measures adopted. This may occur mainly in areas that, at first glance, are not directly related to the loss reduction objective.

Box 5.2 presents a particular case in which, although the electricity distribution company managed to reduce losses over a decade, they returned to the initial high levels due to external factors. We also analyze the multiple strategies implemented by the company to manage non-technical losses. This case illustrates how the interrelation of various factors requires a solution that is both comprehensive and coordinated, involving the participation of several sectors.

Effective reduction of electrical losses requires the implementation of a collaborative intersectoral strategy, integrating various stakeholders within a regulatory framework, aligned with predefined objectives.

Figure 5.2 Trends for electricity losses in the distribution sector in countries that have implemented reduction measures



Source: Authors' elaboration based on information collected by the IDB Infrastructure Department.

Note: Graph A presents the losses disclosed by Chilectra in its annual reports. Graph B, on the other hand, shows the loss figures for distribution in Ecuador, taking as reference the annual reports of ARCERNNR. Graph C reveals the loss levels reported by CFE Distribución in its annual reports, using the energy received at medium voltage levels as an indicator. Finally, Graph D illustrates the distribution losses reported by ANDE.

A. Measures applied in Chilectra and subsidiaries, Chile[27]

Chilectra[28] constitutes a representative case of the importance of deadlines for reducing electricity losses and the need to implement continuous measures to keep them under control. In 1983, the company recorded loss levels close to 22.6%. Towards the end of 2016, they fluctuated by around 5%. Over three decades (1980s–2020s), the company maintained the continuity of its actions aimed at reducing non-technical losses and improving the technical efficiency of its distribution system.

The first step involved preparing an exhaustive diagnosis of the severity and causes of the problem in 1983. Massive energy theft was found to be the main cause of the losses. They verified the existence of more than 210,000 illegal connections, which appropriated 210 kWh/month on average. Of these, the most recurrent modalities were direct illegal connections to low-voltage networks (50%), illegal connections to homes (40%), and meter tampering (10%). Similarly, an interesting aspect of this analysis was that they determined that the spread of energy theft was associated with a component of social contagion. Based on this, the company implemented the following measures:

Technical measures

These consisted of modifying the design of low-voltage networks, which included the total replacement of traditional networks with anti-theft networks (economic air distribution system (DAE)[29] and concentric air distribution system (DAC)[30]), to periodic readjustment in response to changes in the forms of theft. Although the DAC system is more recent than the DAE, during the time in which both were developed simultaneously, DAE-type solutions were used for clients who mainly had single-phase connections, whereas DAC-type solutions were preferred in areas where existing connections were three-phase and potential for growth in consumption was detected due to changing habits. Currently, the DAE system is no longer in use. Traditional networks were replaced in areas where a more significant presence of irregular connections was detected, which caused an increase in economic losses due to the early withdrawal of assets. In addition to the aforementioned readjustments of the accessories of the anti-theft systems already installed, massive plans were made to change the traditional connections (phase and neutral) to concentric cable connections.

27. Based on Valenzuela and Montana (2005) and the company's annual reports.
28. On October 4, 2016, the shareholders decided to change the name of Chilectra to Enel Distribución Chile.
29. Serving consumption mainly through single-phase low-capacity transformers (5, 10 and 15 KVA). This system, in addition to eliminating vulnerable points in low-voltage distribution, has a small number of customers (12) connected to a transformer.
30. It consists of using pre-assembled aluminum cable and conventional distribution transformers as a low-voltage network.

Commercial measures

These were adopted to provide payment facilities to low-income customers most prone to establishing irregular connections. To this end, regularization programs were implemented for users (who initially did not have formal connections and were not properly registered as company clients), payment facilities for overdue debts, and satellite offices and collection positions (mobile and fixed).

Punitive measures

These focused on using legal means to punish theft. In this sense, it should be noted that theft of electrical energy is classified by law as a crime and carries prison sentences and fines. The implementation of the process to arrest perpetrators of theft and the filing of complaints and massive withdrawal of fraudulent connections, with the subsequent broadcasting of convictions on the radio and in the written media, contributed to the community's involvement in the objective of reducing theft. A telephone hotline and online form were implemented so that energy theft could be reported.

In recent years, the company has continued to implement loss-reduction measures.

1. Network automation: As of 2015, 700 remotely controlled devices in a medium-voltage network were managed remotely. In 2021, the company has reached 2,634 remotely controlled devices managed by the Network Operation Center.
2. Smart networks: Between 2017 and 2020, the company planned to migrate to smart grids. Recently, the company implemented the "Grid Futurability" project, which will facilitate the identification and prioritization of grid expansion and modernization in the coming years. It seeks to optimize the use of current facilities, promote resilient, inclusive, and sustainable distribution grids, and integrate smart grids into them.
3. Using thermal imaging in cabinets and control panels in high-voltage grids makes it possible to detect anomalies before they fail.
4. Expansion of transformation and interconnection capacity
5. Opening up new commercial offices.
6. Improvements on websites and mobile applications, all of which improve self-service and consultation processes.
7. Installation of smart meters. In 2021, the company had more than 348,230 smart meters.

The electrical distribution system in Ecuador[31]

In the case of Ecuador's electrical distribution system, actions aimed at reducing electricity losses were carried out within the framework of a national plan with extensive support from the regulatory body (National Council of Electrical Energy, CONELEC) and the central government. Three of the main actions that led to a downward trend in electricity losses stand out.

Adaptation of sector-specific legislation and regulations:

1. Regulation No. 3/99 was published in March 1999, establishing an admissible annual percentage of non-technical rate losses. The resolution determined that for 2002, the limit to be recognized in this regard would be 2%. This goal was later deferred in 2005.[32] Although this ambitious goal could not be achieved, the provision motivated the creation of distribution companies with specific departments dedicated to controlling electricity losses. According to the 2021 Electrification Master Plan, the loss reduction goal is established at 8.92% by 2027.

2. In August 2006, a reform of the Electrical Sector Act was implemented to combat electricity theft. In September 2006, reforms were approved under Act No. 2006-55, which allocated financial resources to investment projects aimed at reducing electricity losses and improving electrical infrastructure and established the possibility of penalizing energy theft.

3. The New General Regulations of the Electricity Sector Regime Act (Executive Decree No. 2066) was approved in November of the same year. In these new regulations, through "Article 12 – Criteria," the National Electricity Council (CONELEC) – in its capacity as the entity responsible for the preparation of the Electrification Master Plan (EMP) – was instructed to proceed with the adoption of specific policies for the rational use of electrical energy to optimize the efficient use of energy and the reduction of losses in all stages.

Allocation of budget items in specific programs

The government of Ecuador allocated USD 256 million to the Loss Reduction Plan (PlanREP) during 2007–2014. From 2006 to 2014, the Ministry for Electricity and Renewable Energy achieved a reduction of approximately 10% in electricity loss, decreasing from 22.2% in 2006 to 12.4% in 2014. These advances represent energy recovery equivalent to $ 200 million per year. According to the 2013–2022 Electrification Master Plan (EMP), the investment necessary for PlanREP in the period 2013–2022 was estimated at USD 365 million.

31. This section is based on the detailed analysis of Tejeda *et al.* (2017).
32. It should be noted that, according to the distribution companies, they were not able to make the necessary investments to comply with the standard established for non-technical losses (Ramos and Neira, 2003).

Designation of planning and control entities

In November 2006, through Resolution No. 260/06, CONELEC approved and launched PlanREP to be executed by electricity distribution companies (EDC) on a mandatory basis within five years. The PlanREP includes the annual planning of the activities to be implemented, proposed, and valued by each EDCs to reduce electricity losses in their respective concession areas. These activities did not differ from those observed in other countries in the region.[33]

The Ministry for Electricity and Renewable Energy

The Ministry for Electricity and Renewable Energy (MEER) of Ecuador is responsible for preparing and publishing the Electrification Master Plan with the support of sector institutions. The 2006–2015 EMP proposed a progressive reduction of national losses until reaching 11.4% on average at the end of the period. As of December 2014, the official registered value reached 12.4% and by December 2018 a value of 11.40% (MEER, 2020).

The Guayaquil electricity company, one of the most notable distributors due to its loss management, implemented specific measures at the electricity company level that explain a notable reduction starting in 2004. In 2006 they started replacing obsolete meters with electronic ones. Subsequently, auxiliary companies were hired to support the reduction of electricity theft, distribution networks were improved and expanded, and in 2010 several measures were adopted to make electricity theft punishable by law. In 2012, regulations were applied that required meters to be placed on the outside of buildings and loss reduction goals were set by business areas. In 2014, legal proceedings were held for energy theft with rulings on the respective fines. Taken together, these measures continuously supported the reduction of losses. Much of the program's success was due to the continuous monitoring of loss-related performance and the adoption of punitive measures against theft, as well as investments aimed at digitizing the measurement and billing of electricity consumption.

33. Among the companies that managed to cut technical and non-technical losses in several countries in the region with the type of measures recorded in Table 5.2 are Codensa (now Enel) in Colombia, Edelnor in Peru, Chilectra in Chile and Edesur in Argentina .

The effectiveness of the Ecuadorian electricity loss reduction program lies in the rigorous monitoring of the underlying causes of losses, measures against energy theft, and strategic investment in the digitalisation of metering and billing. These combined elements have promoted more sustainable and efficient electrical infrastructure.

Federal Electricity Commission (CFE), Mexico

CFE Distribución, which is publicly owned, is the only electricity distribution company in Mexico. Its electricity losses in 2017 were equivalent to 13.97%, of which approximately 60% were linked to non-technical losses. According to the country's Electric Power System Development Program (PRODESEN), non-technical losses that year were equivalent to income losses of USD 1.6 billion. In 2020, the overall losses amounted to 13.84%, which represented a rise when compared to the 13.07% recorded in 2019. This increase was directly attributable to the COVID-19 pandemic, as elaborated upon in the previous section. However, by the year 2021, the overall losses were expected to decrease to 13.78%. This implied a slight improvement compared to the results obtained in the preceding year.[34]

The CFE has made efforts aimed at achieving the goal of reducing electricity losses by 1% each year. The Ministry of Energy (SENER) sets annual loss reduction objectives for the coming years through PRODESEN. For example, in 2018, goals were set to reduce the percentage of losses to 8% in 2024,[35] and investments of USD 7.2 billion dollars in the period 2018–2032 were aimed at improving, modernizing, and updating the distribution infrastructure. It also seeks to incorporate the technology necessary to operate a smart power grid. It should be noted that a large part of this investment is used to address technical losses. In addition, PRODESEN indicates budget items for reducing non-technical losses, including escalation of AMI measurements, replacement of obsolete meters, regularization of working-class neighborhoods, and installation of connections and meters, which specified a budget allocation of USD 4.4 billion in 2018–2032.

The reduction in losses observed in the last decade can be attributed to the strategies implemented to reduce the irregular consumption of electrical energy and investments in modernization and optimization projects of general distribution networks. The main measures[36] implemented by the CFE to reduce non-technical losses are::

1. Measurement assurance: Revision of field measurement systems to locate anomalies in service. In 2017, the CFE conducted a total of 3.2 million inspections, of which 507,397 anomalies were identified. By 2021, the number of revisions had doubled, reaching 6.4 million. In 2021, these inspections allowed for the detection of 8,936 GWh of lost energy, of which 2,369 GWh was recovered and billed.

34. Annual Report 2021 and PRODESEN 2018-2032.
35. According to PRODESEN 2022-2036, losses are expected to account for around 11.2%. It is worth mentioning that many of the benefits planned in 2018 were impacted by the socioeconomic effects of the health emergency and economic crisis caused by COVID-19.
36. As an example, the results of these measures are shown according to the CFE Annual Report of 2017 and 2021.

2. Modernization of metering: replacement of obsolete and damaged meters with state-of-the-art meters, including basic electronic meters, self-management, scaling, and advanced metering infrastructure (AMI). In 2017, the CFE carried out comprehensive modernization, which included updating two million meters. In 2021, the company replaced 1.8 million obsolete meters.

3. Strengthening the commercial process: increasing sales through correct billing to the user. In 2017, 645,000 service requests were handled, and 348,000 irregularities were resolved. By 2021, this strategy managed to increase sales by 11,613 GWh.

4. Regularization of settlements and users: regularizing the electrical energy supply in illegally connected settlements. In 2017, 28,932 new users were regularized and incorporated into the distribution networks. More recently, this strategy has managed to regularize and integrate 249,000 users into the distribution network in 2020 and 309,000 in 2021.

National Electricity Administration (ANDE), Paraguay

In 2006, the total electricity loss in Paraguay was close to 33% (compared to an average of 15% for Argentina and Brazil). Of these, 8% were estimated to be in transmission and 25% in distribution. Of the total, one-third corresponded to non-technical losses caused mainly by broken or missing meters, clandestine connections, fraud, and deficiencies in property titles and customer records.

Mid-2004 the electric utility company created a special office to manage losses. In 2006, ANDE drafted an energy loss recovery plan to achieve a minimum reduction of five percentage points over the following three years.[37] A significant investment effort was required to replace obsolete equipment or equipment with an insufficient operational capacity. Non-technical losses were addressed through ANDE actions and with the government's support within the framework of various initiatives, such as the National Energy Efficiency Plan of the Republic of Paraguay (2011) and the National Energy Policy (2016). These documents established guidelines, strategic goals, and tools for efficiently using energy resources. Both programs seek to guarantee energy security through criteria of self-sufficiency and efficiency, minimizing costs, and assuming social and environmental responsibility to accompany the productive development of the country.

Initially, the loss reduction program achieved little progress, owing to its context's social complexity and the transmission infrastructure gap. The total losses increased from 33% in 2006 to 31% in 2012. Of the total losses reported in the previous year, it is estimated that approximately half correspond to theft or illegal connections and the other half to overloads in the transmission networks, which in turn is due to obsolete infrastructure in urban areas with accelerated and disordered expansion patterns. During this period, this delay in investment translated into a high cost for ANDE, estimated at approximately USD 180 million annually, for electricity losses in urban areas alone.

A notable aspect of ANDE's experience is its holistic approach and the consistency of actions implemented to address the problem of losses. In particular, the measures adopted by ANDE are part of its Generation, Transmission, and Distribution Master Plan, its goals of reliability and quality in electrical supply, its efficiency goals, its rate structuring, and, more recently, its Information

37. With support from the Inter-American Development Bank.

and Communication Technology Master Plan. The general message conveyed by this internal coordination of company policies is that various measures are complementary and synergistic in terms of actions and goals.

Another lesson from ANDE's experience is that the problem of electricity losses is complex: it is not only related to the technical aspects of coordinating the national electric power system or the need for investment in new infrastructure but also to the social complexity inherent to energy theft. For this reason, the goals regarding electricity losses were set for a sufficiently long period, as this would make it possible to meet substantial investment needs and use appropriately targeted social programs to support vulnerable population groups.

Although the sustained losses are above the goal set, gradual reductions have been observed, particularly since the beginning of the last decade (from 2012 onwards). In 2019, losses of 25.1% were reported, of which 5.1% were transmitted and 20% were distributed. The difficulty in maintaining investment levels and their implementation partially explains why greater reductions have not yet been achieved. For example, investments made in 2014 amounted to USD 226 million, well below the USD 769 million that had been considered.

It is worth mentioning that, in parallel and despite these difficulties, ANDE has consistently advanced in its objective of improving the electrical services it provides. In addition to the gradual reduction in electricity losses, the frequency of interruptions has decreased from 32.38% in 2016 to 22.81% in 2020.

The main actions carried out by the company are as follows:

1. Improvement of transmission and distribution networks and substations.
2. Regularization of the service in vulnerable neighborhoods.
3. Updating public lighting records.
4. Deployment of new technologies, such as advanced metering infrastructure (AMI) and automatic meter reading (AMR)
5. Investment in georeferenced information systems of users and assets installed on the grid.

An underlying element of vital importance in this loss reduction strategy is that the company sought to improve the quality of electrical and customer services to create social awareness of the benefits of formalizing connections. ANDE continues investing in information and communications systems that facilitate and speed up user interactions, including virtual service centers, online file management, and payment services.

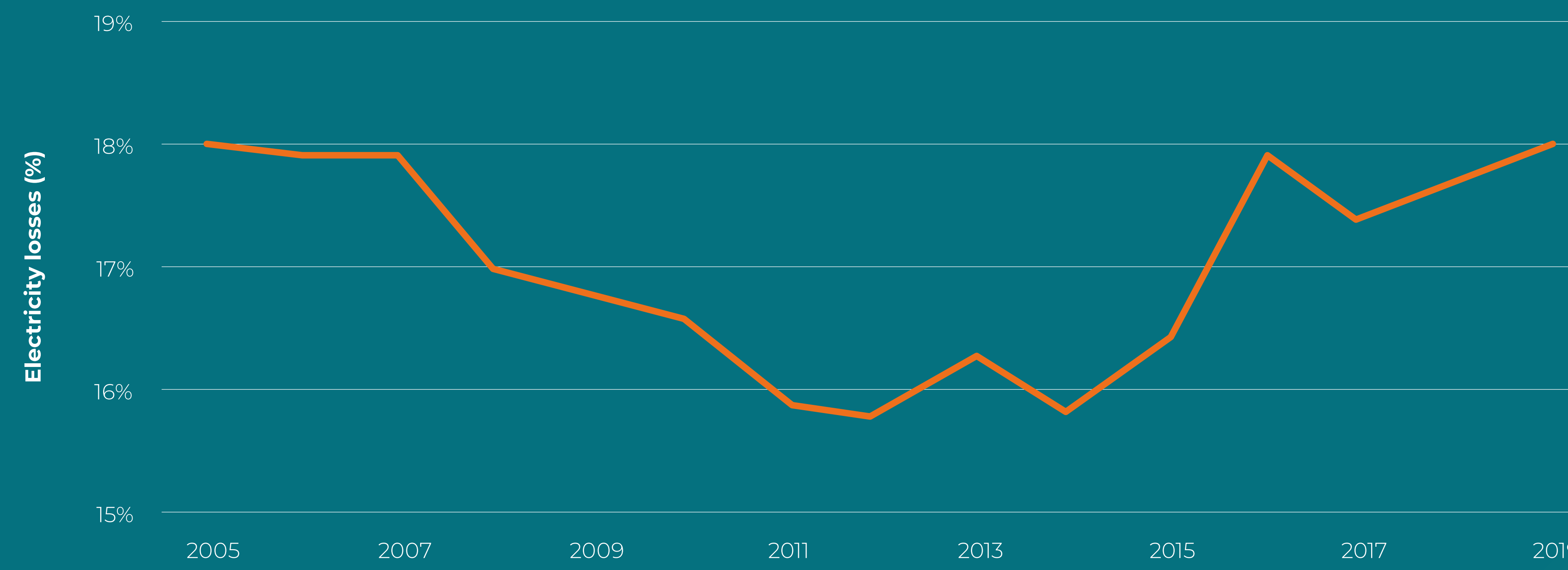
Additionally, since the beginning of 2010, ANDE has implemented the Subsidized Rate program, the objective of which is to improve affordability among low-income families. This program benefits households in poverty and extreme poverty, whose monthly consumption is less than 300 kWh, which is achieved through subsidies ranging from 25% to 75% of the single-phase residential rate. The coverage of this program has expanded since its launch, reaching over 240,000 families by 2020.[38]

ANDE's strategy is part of an ambitious plan for digital migration and strengthening human capital. For example, the company is carrying out the digital transformation of all administrative procedures to improve efficiency in the management of the entity's resources. Regarding the management of electric power system assets, the company has implemented the e-terra SCADA system, whose characteristics and technology provide the information required to operate the system in real-time. This allows for online monitoring of substations and integration with the transmission and distribution of electrical study modules and information exchange with the corporate network.

38. This represents approximately 50% of families in poverty in the country.

Box 5.2 Challenges in sustained reduction of electricity losses in Uruguay: a multidimensional problem

Figure 5.2.1 Evolution of electricity losses in distribution networks in Uruguay



Source: Prepared by the authors based on UTE's annual reports.
Nota: The figure shows the values of losses corresponding to December of each year.

Since 2005, the National Administration of Electrical Power Plants and Transmissions (UTE)[39] has followed specific plans put in place to detect and correct irregular situations, in addition to implementing actions to improve connection infrastructures (such as house connections and measurement points). These measures made it possible to maintain a trend of reduction in losses during the period 2005–2010, despite the odd fluctuations. A significant decrease in losses was achieved through the strategic implementation of these measures, which declined from 18% in 2005 to 15.8% in 2014. However, starting in 2015, factors such as weak economic growth, increased unemployment, and climate variability caused an increase in this indicator. This upward trend shows the intricate nature of the problem and highlights the difficulty involved not only in maintaining low levels of losses but also in preventing their increase. Such a panorama suggests that the approach to addressing this problem should be multisectoral, since it cannot be managed efficiently from a single perspective.

39. Case study based on several annual reports.

On the other hand, it is crucial to examine the strategies that the UTE has deployed and that have played a significant role in the management of electricity losses. Within non-technical losses, UTE distinguishes between clandestine connections (theft) and meter intervention (fraud). Both modalities are classified as crimes in the Penal Code.

The lines of activity of the UTE are grouped into two blocks.

Detection and correction of irregular energy use

Relying on various systems, UTE identifies irregular situations, investigates them, prepares a report, and notifies the customer. Inspections are carried out on those supplies for which a decrease in monthly consumption is detected using different techniques. Additionally, inspections are conducted based on third-party reports. Depending on the type of customer, this triggers an internal process within UTE to address the irregularity, which goes through three stages::

1. Operational process: This concludes with the regularization of the measurement station and may include interruption of the service.

2. Economic process: This concludes in reassessment for any unbilled energy with the corresponding surcharges.

3. Criminal process: This concludes with the filing of a criminal and/or police complaint by the UTE.

Through its Social Inclusion Program, UTE has created conditions for electrical service accessibility and sustainability for households in situations of socioeconomic vulnerability. Within the framework of the particular health conditions that the country experienced during 2020 due to the pandemic, 5,987 connections were made in this segment of the population (UTE, 2020).

With respect to corrective measures, the company carries out adjustments to the measurement station and the facilities. At the same time, regular records are kept of the useful life of the meters and obsolete ones are replaced.

As a preventive measure, the UTE offered the “Opportunities for regularization” program. Between 2005 and 2010, the institution implemented a mechanism through which any clients who notified their offices of anomalous situations in their measurement and control facilities would benefit from their correction. It was established that there would be no consequences for the client, as long as they remained in a regular situation for a period of no less than one year. In the case of clients with debt, the program included a possibility of financing in up to 36 installments with 0.9% monthly interest.

Facilitate access to electrical energy

The UTE recognizes that one of the causes of energy theft is the lack of service and the economic limitations of users. For this reason, access policies were formulated in low-income areas, which offered the following advantages:

1. Free electrical connection to the UTE network.

2. Advice for indoor installation.

3. Financing in installments and without interest of the differential switch and grounding, two basic elements for the safety of the indoor installation.

4. Commercial discounts on the residential rate. The UTE relied on the criteria of the responsible authority in the matter, namely the Ministry of Social Development (MIDES). It defines, through socioeconomic indicators, who is eligible to receive these commercial discounts.

In addition to the two areas of action mentioned above, the UTE relies on three additional instruments: the implementation of a subsidized rate (reduced rates for vulnerable groups), supervision and monitoring within the framework of their strategic planning, and effective communication with the public and with specific interest groups.

Since 2012, the company has been gradually implementing the installation of smart meters. According to the UTE's annual report, 2020 ended with 900,000 meters purchased, of which 418,000 have already been deployed, for a connection rate of more than 99%. This technology will allow for developing capabilities of automatic and remote readings, with which the client can be informed about their daily consumption through multiple channels, as well as conducting global and efficient management of the entire billing process, including disconnection/reconnection and adjustment of contracted power. Alarm signals and event detection from smart meters, together with the analysis of hourly consumption data, will help the UTE identify and prevent non-technical losses.

Since 2013, the company has been migrating its Commercial Information System. The program, implemented in 2015, is supported by an Integrated Operating System (IOS) that makes it possible to locate unpowered grid elements and evaluate technical and non-technical losses in low voltage installations.

Although UTE has achieved favorable results in its strategy for reducing electrical losses, external factors to the company have contributed to an increase in these losses. The company's current challenge is to mitigate the causes of the increase in non-technical losses by promoting greater affordability of electricity.

5.3 Conclusions

The design of policies and regulations aimed at reducing electricity losses in Latin American and Caribbean countries can benefit from an analysis of the experiences of neighboring countries. Considering the high level of diversity in local circumstances, these experiences can provide valuable elements for the design and planning of effective policies. The experiences discussed in this chapter address some of the experiences in the region by identifying some common patterns but also recognize that there are no unique recipes regarding the design and implementation of electricity loss reduction policies.

Indeed, in LAC countries such as Chile, Ecuador, Mexico, and Paraguay, electricity losses have been reduced through successful strategies that involve measures both at the level of the institutional framework of the electricity sector and at the level of companies that operate in the sector. Among the elements found in common, we note that these strategies were based on clear institutional support, a diagnosis of the prevailing situation in the sector, an increase in resources to strengthen and update the electrical infrastructure, the creation of entities focused on planning and control of the electric power system, commercial measures focused on increasing the payment capacity of users, and punitive measures for offenders.

Perhaps, the most distinctive feature is the effort to reduce losses through institutional and regulatory policies. In general, these policies have tended to promote a better distribution of responsibilities among different actors in the market and the creation of incentives. In LAC, the implementation of price incentives seems to have been an effective measure to encourage companies to reduce their losses. Clearly, the implementation of policies has been and will be different depending on the particularities of each context. However, it is essential to design and implement these reforms under the conditions of accountability, communication of benefits, and political consistency. The predictability or stability of regulatory frameworks represents an essential element of the foundation for promoting long-term investment programs by electric utility companies. Otherwise, reforms could have a reduced impact or be temporary in nature.

Building institutional credibility is not a simple task. The process of enhancing the long-term prospects of developing countries is subject to being impeded by short-term setbacks. This is particularly apparent in the fundamental infrastructure sector, which is characterized by the significant social and economic vulnerabilities of these countries. At the same time, it must be recognized that without such institutional solidity, the levels of efficiency and quality of the region's electric power systems will diminish, harming the most vulnerable populations.

In line with the above, a multi-sectoral approach seems to strengthen the institutionality of the measures aimed at addressing the problem of electricity losses. On the one hand, the objective is to improve the electrical infrastructure and its operational performance. However, it is necessary to address the causes that make citizens connect to the network irregularly (or tamper with connections). For example, land registry (and land title registration) campaigns as well as social campaigns tend to be an organic part of the loss reduction programs executed by electric utility companies. In fact, these are complemented by government social programs established at the national level to meet the energy needs of the most vulnerable populations. These efforts involve not only electric utility companies under a broad understanding of the problem (technical and social) but also require a high level of coordination with other sectors (such as national land-use planning and social development entities).

Some common factors can also be seen in operationalization by electric utility companies in their respective areas of service. The primary and most evident factor is the implementation of long-term strategies that involve investment plans aimed at enhancing and broadening physical infrastructure and investing in human capital. There are no simple solutions; controlling and reducing loss levels will involve long investment processes for electric utility companies and, in addition, may mean a learning-by-doing process. This last element is perfectly valid given that the problem of losses involves a certain social complexity, and these investments entail an essential modernization process for the sector. On the other hand, the benefits from these investments can begin to be captured even in the short term, in the form of better collection levels and higher levels of productivity and profitability.

A second aspect that deserves to be highlighted is the adaptability of loss-reduction strategies to new technologies as they become available. In the current context, it is almost impossible to propose a loss-mitigation program that does not contemplate a comprehensive process of system digitalisation. The growing digitalisation of electric power systems facilitates more efficient and effective monitoring and control of energy flow. Digitalisation also makes it easier to deliver other benefits to customers, such as providing better information on consumption and serving distributed generation points. Moreover, innovations in the sector, such as prepaid meters, allow customers to gain greater control over their consumption and payment frequency. In general, technological innovations in the sector offer greater flexibility to attack sources of electricity loss.

Chapter 6

Digitalisation and the private sector[40]

40. Chapter prepared by Johanna Gomez Velasquez, Elizabeth Layton Herrera and David Matías.

Over the last decade, the energy sector has experienced notable technological changes. In line with this global trend, the experience of the electricity sector has shown that the emergence of new technologies presents opportunities to face problems such as electricity losses in a cost-efficient manner. However, there is much room for progress in terms of digitalisation as well as intensifying its use to reduce and control loss levels. The investment requirements for this purpose constitute a no small challenge. In particular, the current context of high interest rates, expectations of low economic growth, and strong fiscal restrictions may reduce the appetite for investment and the investment capacity necessary to modernize our electric power systems. Against this backdrop, this chapter focuses on discussing the role and potential of the private sector as a driver of technological modernization in the Latin American electricity sector.

It's important to highlight that the modernization process of electrical systems is independent of the ownership structures of the companies involved. Therefore, the digitalisation processes are not particularly associated with any specific type of ownership. However, considering the growing investment needs anticipated in the electricity sector, there is no doubt that private participation will have to play a central role in accelerating the modernization of infrastructure. This chapter begins by introducing a contextualization of the challenges involved in technological adoption and expansion within the electrical sector. It also comments on the main technologies adopted and their potential benefits with respect to loss reduction and control programs, and discusses the opportunities offered by private participation in the processes of modernization of the electricity sector and reduction of energy losses. Finally, we describe practical cases of private companies that have established loss-reduction strategies through digitalisation.

6.1 Modernization of electric power systems

The modernization of the distribution sector leads to increased operational efficiency for electric companies, resulting in a significant reduction in losses. However, such modernization involves confronting multiple challenges. Incorporating new technologies is a process that develops gradually, presents complexities, and requires significant investment. In addition, an appropriate regulatory and institutional framework is essential to guarantee effective implementation.

Technological adoption is part of the natural process of replacing networks and systems that have gradually become obsolete in the face of new realities and user needs. Technological adoption processes are therefore expected to be carried out gradually, balancing the useful life periods of the assets, the development of new technologies, and the capacity to adopt them. Apart from being gradual, this process must be constant to ensure continuous evolution based on market demands and technological advances.

Modernization is a long-term process that can be complex to implement. This means investing in deploying new equipment, updating software, and training human talent to extract maximum benefits. For example, the technologies that have emerged and are increasingly being adopted by electric utility companies are mainly related to managing the flows of transported energy. This largely involves investments in physical assets, such as smart metering and software, for their management (IEA, 2017; Wolak & Hardman, 2021). In other words, the usefulness of deploying next-generation physical assets depends on the company's ability to manage the information generated by these assets, representing an intangible asset of increasing value in the industry.

Therefore, the magnitude and speed of investments are central issues in planning to modernize electric power systems. Both the magnitude and speed are closely linked to the investment, debt, and execution capacity of electric utility companies. As these are intensive capital formation processes, with long-term horizons between their implementation/construction processes until their operation (and investment recovery), they require a financing profile and investors with adequate deadlines and the capacity to invest large amounts in a manner consistent with the needs of the infrastructure.

Other key criteria that facilitate modernization and digitalisation processes include scalability, robustness (technologies with a proven track record), and the feasibility of application and use in the contexts in which electric utility companies operate. These criteria can reduce technological risk by simplifying the implementation. However, it is important to note that the market environment and regulatory conditions can influence the drive to invest even when these criteria are adequately met.

These characteristics strongly condition how and to what extent modernization processes can occur. For example, as expected, in the context of significant investment gaps, the Latin American electricity subsector has been characterized by adopting technologies in an advanced state of maturity rather than by betting on innovations in the industry. Likewise, it is unsurprising that investment in research and development (R&D) in the region's electricity transmission and distribution companies is comparatively low.[41]

Thus, a trend is essentially reactive to technological advances exacerbated by the need to adapt these tech-

41. For example, according to data from the Energy Research, Development, and Demonstration (RD&D) Budget of the International Energy Agency (IEA), it is evident that during the period from 2015 to 2020, both the Chilean and Mexican governments invested an average of 0.02% and 0.09% of their Gross Domestic Product (GDP), respectively, in energy-related RD&D. In contrast, certain high-income countries allocated more than 0.3% of their GDP to these same areas. Notably, this includes Germany, Austria, Belgium, Finland, France, the United States, and the United Kingdom.

nologies to specific local conditions. This generated a delay in the digitalisation of the sector. Therefore, there is latent concern about whether the pace of technological adoption in the electricity sector will satisfy the need to integrate innovations, such as those aimed at addressing the problem of energy losses.

Use of new technologies to reduce and control losses

Digitalisation in the electrical distribution sector contributes significantly to minimizing electricity losses by reducing costs and improving operational efficiency. This improvement is intensified by new technologies that improve the measurement of consumption, optimize energy management, and detect anomalies more effectively. In addition to reducing loss levels, service quality benefits from the modernization of energy transportation infrastructure. This not only improves the operational efficiency of the system but also facilitates the integration of distributed energy sources and the adoption of strategies to manage demand, such as time-of-use rates (Wolak and Hardman, 2021).

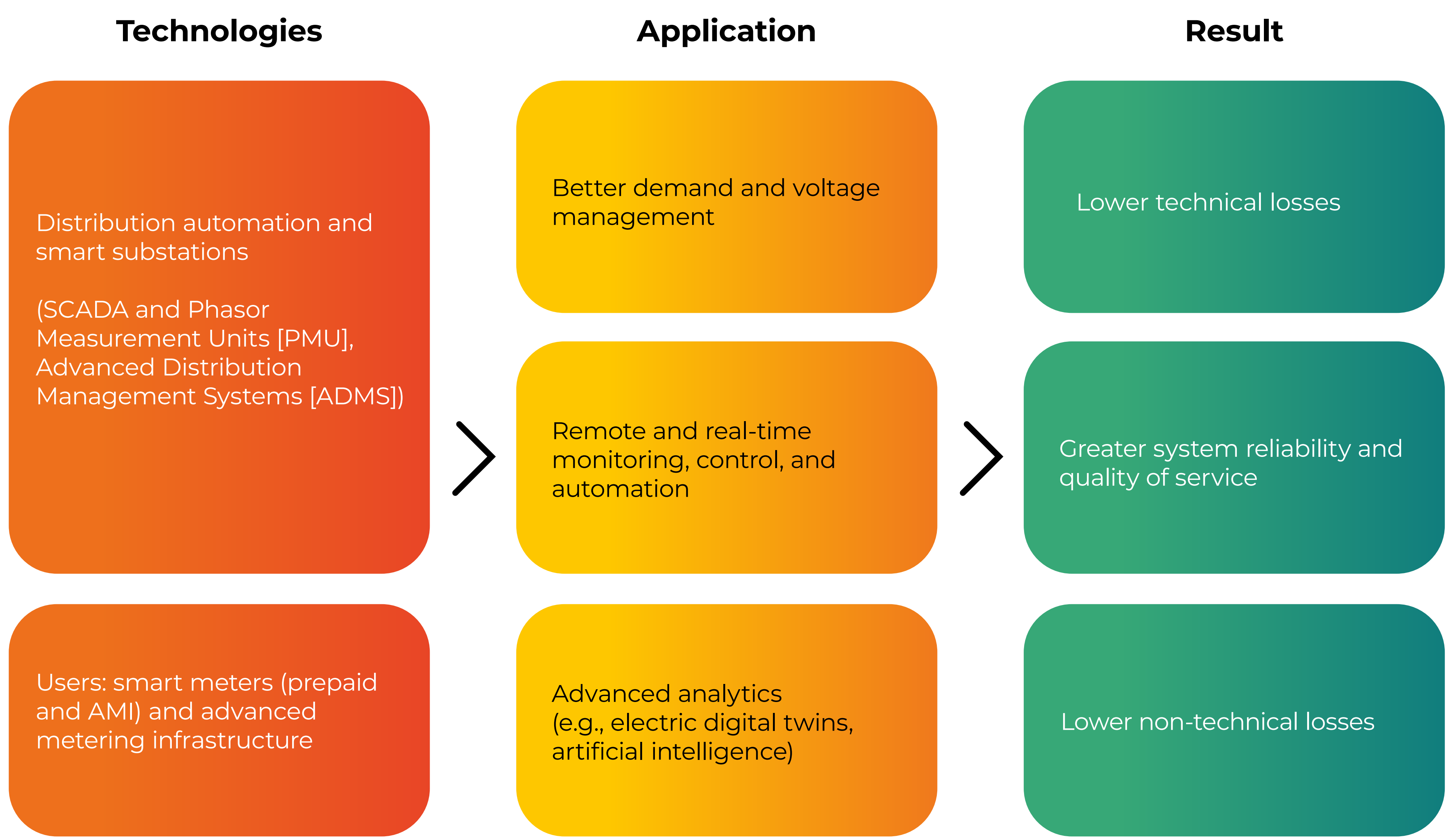
The adoption of emerging technologies such as those highlighted in Figure 6.1, along with the intensive use of data, is transforming the electricity sector with the development of smart grids. These innovations, in addition to improving voltage and demand management, make it possible to minimize both technical and non-technical electricity losses. The combination of digital tools and advanced devices ensures the effective and real-time coordination of distribution and transmission assets (Department of Energy, 2022; Levy et al., 2023). This optimization results in a more resilient electrical grid that is capable of responding promptly to variations in demand and is more effective in identifying and correcting problem areas, thus improving the efficiency of the electric power system.

Consumer-side technologies include smart meters such as Advanced Infrastructure Meters (AMI) and prepaid meters. In particular, AMIs have the ability to collect large amounts of consumer data. This massive data collection generates a constant flow of information that can provide valuable insights for network management. If these data are integrated with information from distribution systems, advanced data analysis techniques can be used to identify anomalies in energy consumption and detect areas for distribution optimization. The implementation of these technologies leads to a holistic enhancement of the power grid. This results in a significant decrease in losses, enhanced reliability and quality of electrical service, and increased efficiency in energy distribution. (Alvarez-Alonso et al., 2023).

In the case of prepaid meters, these constitute an example of the adaptation of technological advances to the characteristics of users. In their most basic form, prepaid meters enable a pay-as-you-go model, in which, instead of paying after consumption, the user pays before. This model provides users with flexibility as it allows them to choose their level of consumption based on the budget they have available. This billing scheme potentially encourages savings and consumption awareness among the users (Kambule et al., 2018). Other significant advantages include exemption of the service from charges for disconnections or reconnections and guaranteeing instant reconnection without waiting periods. An additional benefit is that consumers are not required to make deposits, thereby easing their financial burden. On the other hand, it can also generate savings for utility companies, as monitoring costs are considerably reduced by eliminating the need for meter readings, bill delivery and collection management.[42]

The critical aspect of the operation of these systems is the communication capacity between thousands of processors, which means that the systems must have the ability to reliably interconnect different protocols and technologies. That is, the usefulness of the new infrastructure depends on the information capacity and knowledge of data analysis. Box 6.1 presents an innovative tool developed by the IDB Group to use advanced analysis models to effectively mitigate electricity loss.[43]

Figure 6.1 Examples of technological innovations to reduce electricity losses and improve quality of service



Source: Prepared by the authors based on Alvarez-Alonso *et al.*, (2023), IEA (2023a), Department of Energy (2022).
Note: For a more comprehensive analysis of emerging technological innovations in the electricity sector, we recommend reviewing the following key references: Alvarez-Alonso et al., (2023), the International Energy Agency report (2017) and the United States Department of Energy report (2022), which offers a detailed overview of emerging innovations in the distribution sector in the United States.

42. It is worth mentioning that low-income customers are charged lower electricity rates.
43. This tool can be found in Code for Development, an initiative that provides a platform for sharing open source software and other resources and to connect with diverse collaborators who support the vision that this software is a public property of the IDB Group.

Box 6.1
Energizados – data analysis program to minimize energy losses[44]

Technological progress has allowed the use of data in more advanced analysis models, such as those offered by machine learning. This tool, applied in various sectors to face challenges, such as the detection of financial fraud, has also been found to be relevant in the electricity sector, especially in identifying energy theft. Despite the potential of these technologies to analyze information from smart meters and grids, their adoption in Latin America and the Caribbean is still in the initial stages. In this context, the "Energizados" project seeks to address electricity losses in companies in the region, where the adoption of advanced meters is emerging and data such as daily consumption are still limited.

Energizados is a solution based on machine learning designed to detect and reduce non-technical losses, shorten regularization times, and enhance precision in fraud identification. This solution, developed by the Inter-American Development Bank, has shown encouraging results, indicating that the applied models could be useful for countries in the region. The application of machine learning algorithms has made it possible for companies to optimize the management of their equipment to resolve cases of energy theft, overcoming the limitations of previous systems that repeatedly sent equipment to the same urban areas.

Empresa Eléctrica de Guatemala S.A. (EEGSA) tested this model using historical user consumption data to identify predictor variables of potential fraud and applied various machine learning models. They then conducted field tests to evaluate the assertiveness rate, i.e., how many of the cases identified as potentially fraudulent by "Energizados" were indeed fraudulent. Of the more than 5,300 users analyzed, "Energizados' detected fraud in 1.52% of the cases. This rate compares favorably to that of EEGSA's historical fraud-detection process, which was 1.42%. Additionally, detection with "Energizados" resulted in the recovery of more than 353,000 kWh of electrical energy and the geographic identification of new fraud locations. When translating this energy consumption into monetary value and considering the low implementation cost of "Energizados," the cost-benefit ratio of the project was 2.88, that is, with a recovery of approximately three times the implementation cost.

44. For a more detailed analysis of the “Energizados” tool, we recommend consulting the study carried out by Giraldo et al. (2022).

Digitalisation and climate change

Climate change introduces additional challenges to infrastructure modernization, which leads to a need to increase the resilience of power grids. The IPCC (2023) indicates an increase in the frequency and intensity of natural disasters, such as heat waves, intense rains, droughts, and cyclones.[45] Against this backdrop, electrical grids, designed and built decades ago, face increasing pressures due to their inherent vulnerability. These systems, designed for a different climate, will face more extreme weather conditions throughout their operational life, which may compromise their ability to meet energy demand.

This situation highlights the importance of minimizing potential damage and guaranteeing the continuity of the electrical supply. In this context, digitalisation emerges not only as a means to improve service quality and reduce losses, but also to strengthen the resilience of electricity grids to climate impacts.[46] Adopting digital technologies, including simulation and modeling tools, allows for optimizing strategic planning, helping the network to better resist the effects of climate change (IEA, 2023a). Also, managing and renewing assets, such as replacing obsolete equipment, is essential to ensure an uninterrupted and reliable power supply.

Integrating climate resilience into the planning, operation and maintenance of electric power systems often coincides with the strategies aimed at reducing losses. It is essential that electric utility companies identify solutions that are cost-efficient and that address multiple challenges, such as reducing losses and improving service quality (IEA, 2021). Collaboration between different levels of government, the private sector and other entities is crucial to develop and select the best resilience strategies (Department of Energy, 2022). This collaboration, complemented by international cooperation and knowledge-sharing, can establish common standards and practices, driving innovation and optimizing costs. This joint effort will facilitate the modernization of networks, better preparing them for extreme weather events.

45. Extreme climate events increase the vulnerability of energy supplies, increasing interruptions and, consequently, hindering progress towards achieving Sustainable Development Goal 7, which seeks to guarantee access to affordable, secure, sustainable, and modern energy for all.
46. Within the context of the electricity industry, resilience is understood as the ability of a power system to withstand interruptions, maintaining the electricity supply to consumers. A system will prove to be resilient to climate change if it can recover quickly after experiencing extreme weather events such as hurricanes, droughts, heat waves, floods, among others.

6.2 Role of the private sector

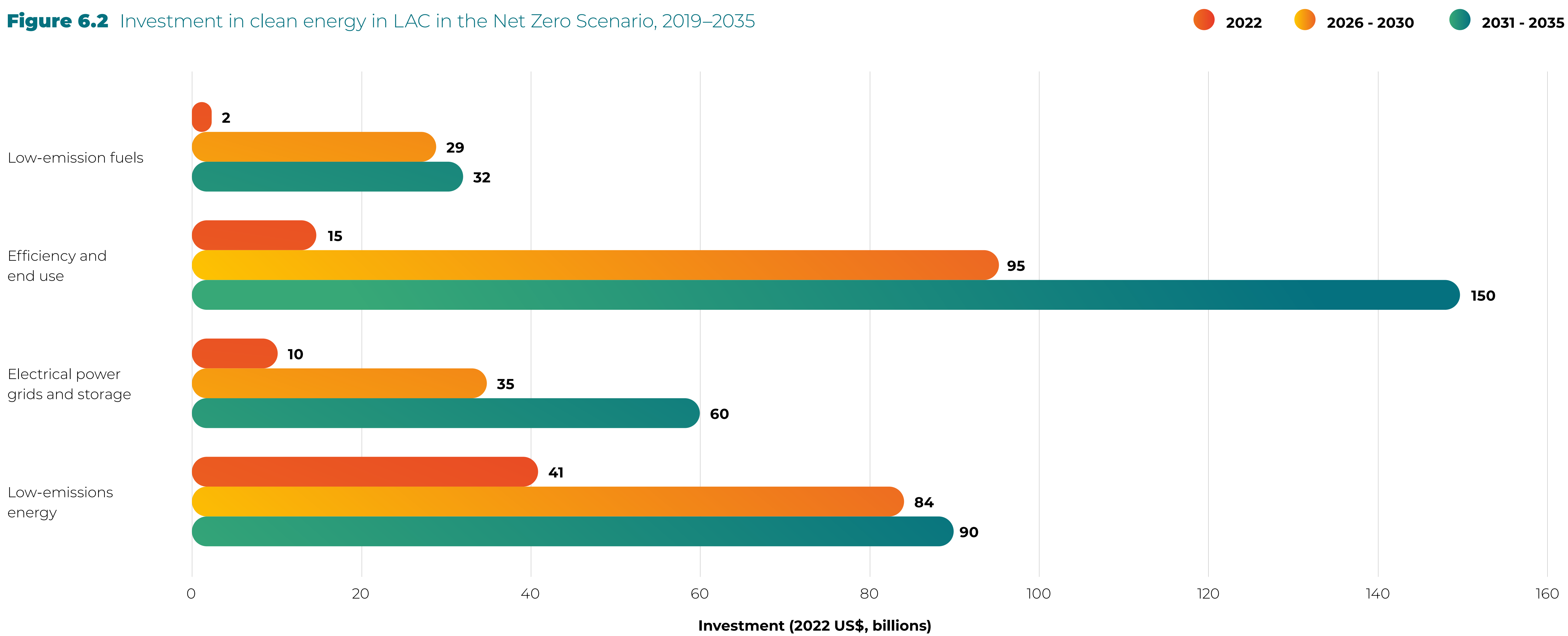
The digitalisation of the electricity sector, added to the urgency of meeting environmental objectives, requires mobilizing large amounts of resources, which need to be financed by both the public and private sectors. Given the panorama of fiscal restrictions in Latin America and the Caribbean, private financing in infrastructure must be expanded to close infrastructure gaps (Powell and Valencia, 2023). Boosting private sector investment will not only alleviate the fiscal burden but will also contribute towards addressing the infrastructure investment gaps that still prevail in the region.

The distribution sector is distinguished by its intrinsic need for large investments of capital aimed at the renewal, modernization, and expansion of its infrastructure. For example, during 2019, more than 50% of the expenses incurred by distribution companies in the United States were allocated to these areas.[47] However, many electric utility companies in developing economies do not have the capacity to make such investments, as they are in financial situations that are not sustainable in the long term. This is largely due to the fact that the rates set for electricity consumption rarely reflect the actual cost of providing the service (Foster and Rana, 2019).[48]

In this sense, the ability of developing economies to mobilize financial resources to modernize their infrastructure will be a determining factor in building a cleaner, more modern and more resilient electricity sector. As shown in Chapter 3, developing regions have the lowest efficiency levels in the electric power transmission system, implying the need for significant investment in their infrastructure. Therefore, increasing annual investment in clean energy is essential to align the meeting of growing energy needs with the objectives of the Paris Agreement.[49] In 2022, Latin America and the Caribbean invested USD 66 billion in this area (see Figure 6.2), but to reach the goal of Zero Net Emissions in 2050, this investment must be quadrupled, i.e. USD 243 billion annually in the present decade (IEA, 2023b). This investment will have to be directed largely to energy distribution and storage (around 15%), and it is estimated that it will have to increase 3 to 6 times its current value to achieve zero emissions goals.

47. During the year analyzed, distribution companies incurred expenses totaling USD 57.4 billion (EIA, 2021). A considerable amount of this (USD 31.4 billion) was specifically allocated to capital expenditures. On the other hand, USD 14.6 billion were channeled into operations and maintenance (O&M) and USD 11.5 billion were allocated to customer-related expenses. This figure encompasses areas such as advertising, billing processes and customer service and support
48. Using a sample of developing countries, Foster and Rana (2019) show that private companies, compared to their public counterparts, achieve better cost recovery and efficiency in electricity distribution. It should be noted that not all private companies have had better performance, with the country's context being a greater determinant of company results.
49. By clean energy the IEA refers to a range of efficient, low- or zero-emission technologies and the necessary infrastructure that can put countries on a robust path to achieving energy-related SDGs and longer-term decarbonization goals, such as net zero emissions by 2050.

Figure 6.2 Investment in clean energy in LAC in the Net Zero Scenario, 2019–2035



Source: AIE (2023b).

Note: The 2050 Net Zero Emissions Scenario (NZE) is a scenario proposed by the International Energy Agency that illustrates the actions required for the global energy sector to achieve net zero CO_2 emissions by 2050. This scenario also aims to minimize methane emissions from the energy sector and establishes concrete actions for the United Nations Sustainable Development Goals related to energy. Low-emissions energy, including renewable and nuclear energy. Investment in electrical power grids and storage is that associated with low-emissions investments. Low-emission fuels mainly refers to sustainable biofuels, low-emission hydrogen and CCUS and related infrastructure. Efficiency and end use refers to improvements in energy efficiency and decarbonization of end-use sectors, such as transportation, industry and buildings.

The transition to clean energy on the required scale demands strengthening public and private investments. In the face of growing fiscal stress, private investment is essential for acquiring resources and technological modernization. According to estimates from the International Energy Agency, approximately 70% of the resources necessary for LAC to achieve the goals of the Net Zero Scenario must come from the private sector. This projection underlines the strategic importance of the private sector in intensifying efforts aimed at modernizing and digitizing the power grid infrastructure.

Developing a comprehensive strategy is essential for effectively mobilizing private sector financial resources to support the modernization of the electricity sector. This must weave together political reforms, the strengthening of institutional and regulatory frameworks, and the implementation of tools for risk mitigation. These mechanisms face the dual challenge of meeting the growing demand for infrastructure in terms of volume and quality while also guaranteeing the provision of services at competitive and affordable costs for consumers (Yépez-García et al., 2022). The public sector is consolidated as a facilitator of private investment, promoting collaboration with the private sector and establishing a solid institutional and regulatory framework for the electricity sector. For example, the strengthening and adaptation of Public-Private Partnerships (PPP) involves the review and strengthening of current legislation, reconfiguration of institutional structures, and creation of units specialized in the management of PPPs (IEA, 2023b; Yépez-García et al., 2022).

Based on an adequate regulatory framework, private investments constitute not only an effective means of expanding and accelerating the modernization processes of electrical grids but are also imperative given the unavoidable need to inject new capital into the industry. In this context, it is important to emphasize that the execution of these investment processes is part of multi-year plans that require substantial and sustained capital expenditure over extended periods. This requires the presence of actors with strong solvency and liquidity in energy markets.

In Latin America and the Caribbean, the articulation of robust regulatory frameworks for modernizing the electricity sector is considered a strategic priority in some countries.[50] This trend reflects the recognition of the importance of adapting to the current global and technological dynamics. In several countries in the region, these regulations seek to establish goals and offer incentives to accelerate investment in new energy assets. For example, Box 6.2 describes the case in which the regulator in Colombia established goals that favored the penetration of smart and prepaid meters.

50. For example, see the study “Analysis and proposal for improvement to the Chilean regulatory framework for the Digitalization of the Energy Sector”. This study developed a plan for the digitalization of smart grids, industry and users in Chile, covering technological and regulatory aspects and focusing especially on electrical transmission and distribution networks. In Argentina, the document "Guidelines for the comprehensive and sustainable development of the electricity sector in the short and medium term" proposes updating and standardizing the regulatory frameworks. This with the aim of integrating disruptive technologies into the sector, such as electromobility, digitalisation and smart meters. In Costa Rica, the National Strategy for Smart Power Grids aims to develop a flexible and modern power grid system. This strategy focuses on using technological innovations to increase efficiency and promote decarbonization, such as measures to confront climate change and promote a transition towards a more sustainable and green economy.

Box 6.2

Promoting the digitalisation of the electric power system through appropriate regulatory frameworks in Colombia[51]

The Energy and Gas Regulatory Commission (CREG) has implemented policies to promote the installation of electric meters. The Commission has established conditions for the implementation of Advanced Metering Infrastructure (AMI) in the National Interconnected System (SIN) as well as goals for the progress of the installation of AMI, including a minimum objective of 75% of users connected with AMI in the commercialization market in the SIN by 2030. With these measures, the following benefits are expected to be achieved:

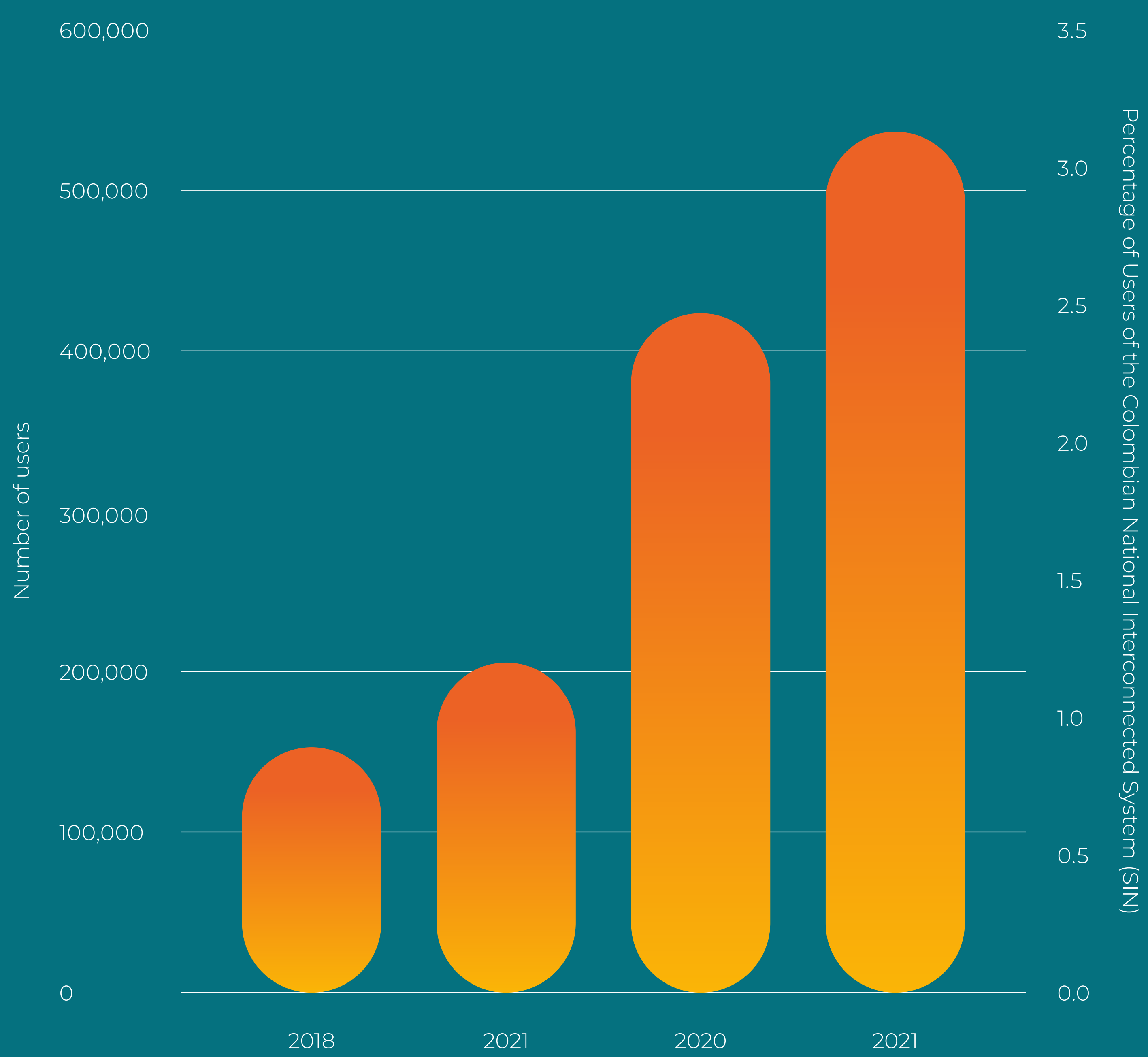
1. Effective management of the reduction in technical and nontechnical losses.
2. Possibility of remote disconnection in cases of non-payment or illegal connections.
3. Improvement of service quality through monitoring and control of distribution systems.
4. Promotion of efficiency in the cost of providing energy services.
5. Facilitation of hourly pricing schemes, and thus lower energy prices.

Since the implementation of the regulation, the digitalisation of electricity consumption in Colombia has accelerated. In 2018 there were 150 thousand meters, while in 2021, there were a little over 500 thousand meters. Despite this, the percentage is considered to be relatively low compared to the goal established for 2030, with only around 3% of SIN users having smart meters (see Figure 6.1.1).

It is also interesting to note that the deployment of modern meters has been oriented mainly to the residential sector and the most vulnerable sectors, which is consistent with the function of reducing and controlling energy losses. Indeed, in 2021, 89% was directed towards the residential sector, while the remaining 11% was allocated to the non-residential sector, with a notable concentration in the commercial sector. Projects for the installation of modern meters have had a strategic focus on the lower-income socioeconomic strata in Colombia in order to overcome measurement and monitoring problems. Figure 6.2.2 illustrates that approximately 75% of smart meters have been installed in the first three socioeconomic strata. Prepaid metering has also been implemented almost exclusively in lower-income socioeconomic strata. This strategy is especially effective in reducing energy losses by minimizing the need for surveillance in homes where the probability of non-payment of electricity services may be higher.

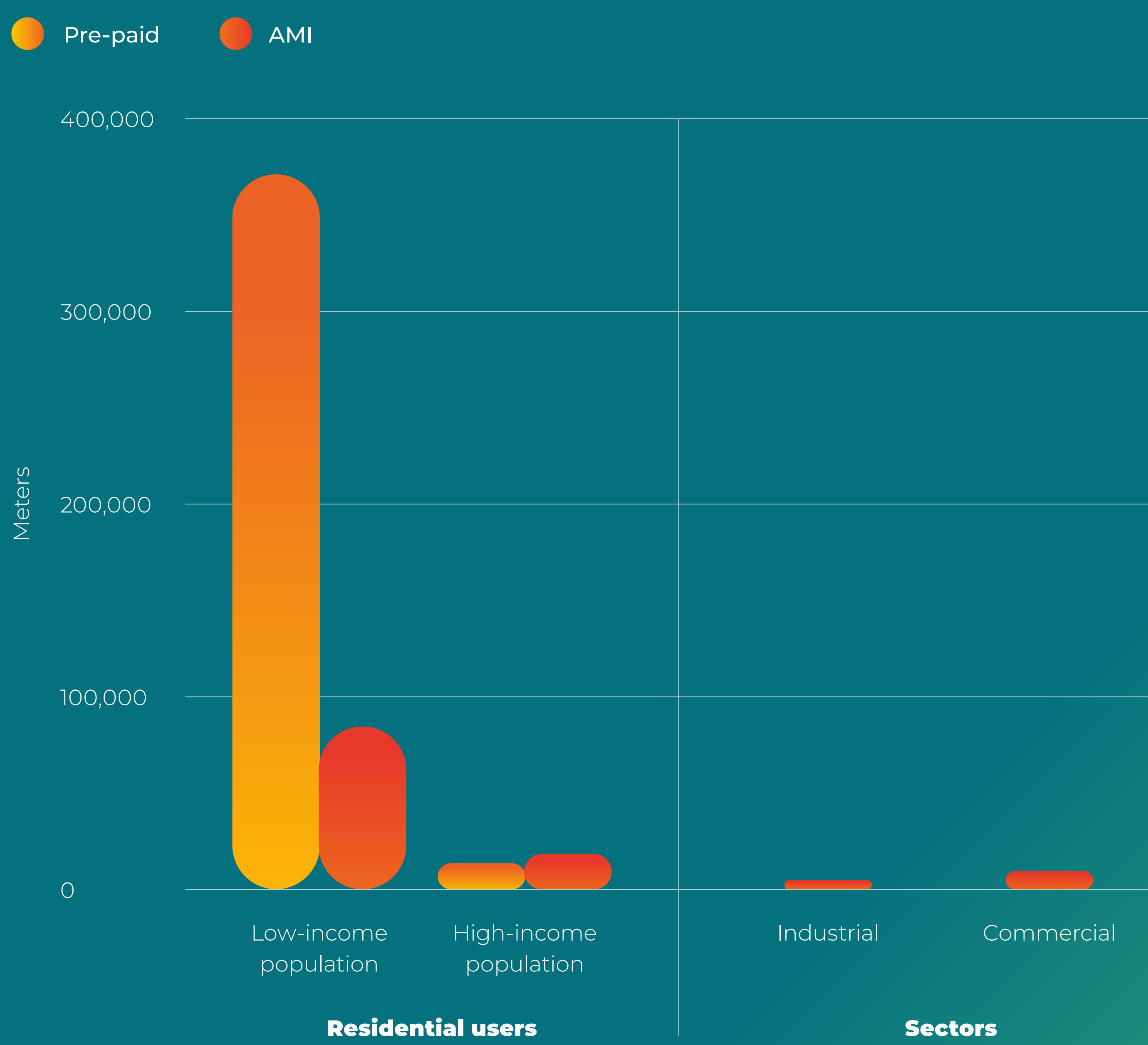
51. Based on the Superintendency of Residential Public Services (2022a, 2022b).
52. With the most recent regulations: Law 2099 of 2021, Resolution CREG-175 of 2020, 101-1 of 2022, and Resolution 40072 of 2028, and Law 2294 of 2023.

Figure 6.1.1 Evolution of AMI implementation in Colombia, 2019-2021



Source: Superintendency of Residential Public Services (2022a).

Figure 6.1.2 Distribution of AMI and prepaid meters by sector in Colombia, 2021



Source: Prepared by the authors with data from the Superintendency of Residential Public Services (2022a).
Note: The low-income strata include strata 1, 2, and 3, while the high-income strata include strata 4, 5, and 6.

6.3 Case studies

In this section, we analyze case studies from different private energy distribution companies in Panama, Colombia, Chile, and Argentina. These companies, framed in their particular context and reality, are driving the sector's modernization, supported by the regulatory frameworks in which they operate, and, in some cases, leverage incentives that stimulate innovation and operational efficiency. Their fundamental loss reduction strategy focuses on the digitalisation of the sector, which ranges from implementing advanced metering infrastructure to using sophisticated data analysis to optimize network operations and maintenance. By evaluating these case studies, we seek to show how the sector is capitalizing on the opportunities offered by emerging technologies to transform energy supply, minimize losses, and ultimately provide users with a more efficient, sustainable, and higher-quality energy service. In particular, we highlight two cases in which IDB invests in financing the modernization processes of the electric power system.

ENSA, Panama[53]

In Panama, three companies are responsible for distributing and commercializing electricity. According to the National Public Services Authority (ASEP) of Panama, in 2022, the total losses in the distribution sector amounted to 1,735 GWh, representing 19.6% of the total energy acquired by these companies. Among them, Elektra Noreste (ENSA) stands out for the volume of electricity it distributes the number of clients, and its service area. ENSA supplies electricity to approximately 42% of the population, which is equivalent to about 2 million people. Its franchise territory includes a significant segment of the population with vulnerable income. For example, nearly 93,600 clients benefited from government subsidies in 2021, which were implemented to mitigate the economic impact of the pandemic on the most vulnerable families. According to the information provided by the company, the monetary value of electricity losses during 2021 and 2022 amounted to approximately USD 5 million per month, of which the amounts not recognized in the rates that the company must absorb are around USD 1 million per month. This represents a considerable opportunity cost since eliminating these losses could increase the income that could be used to cover operating expenses or make investments in improving infrastructure.

The ENSA has invested USD 55 million annually in the country as capital expenditure (CAPEX) over the last four years and expects to maintain this investment rate for 2023–2025. A significant challenge in addressing a company's problem of electricity losses lies in ensuring adequate financing for implementing strategies and

53. Based on the company's annual reports.

programs to minimize the costs of this problem. In this context, IDB Invest will provide partial financing to cover the company's investment needs in the coming years, intending to cover financing gaps for the modernization and expansion of electrical power grids.

Capital investments financed by IDB Invest (USD 100 million) constitute a strategy to increase access to electricity services on the grid, maintain adequate quality of electrical services, and reduce electricity losses. ENSA's experience allows us to appreciate the consistency needed in implementing investments to improve electric power systems to control loss levels at relatively healthy levels and the difficulty of achieving higher efficiency levels from such investments. Thus, electricity losses are anticipated to fall from 10.32% in 2022 to 9.97% in 2026 due to the year-on-year investment plan (see Figure 6.3).

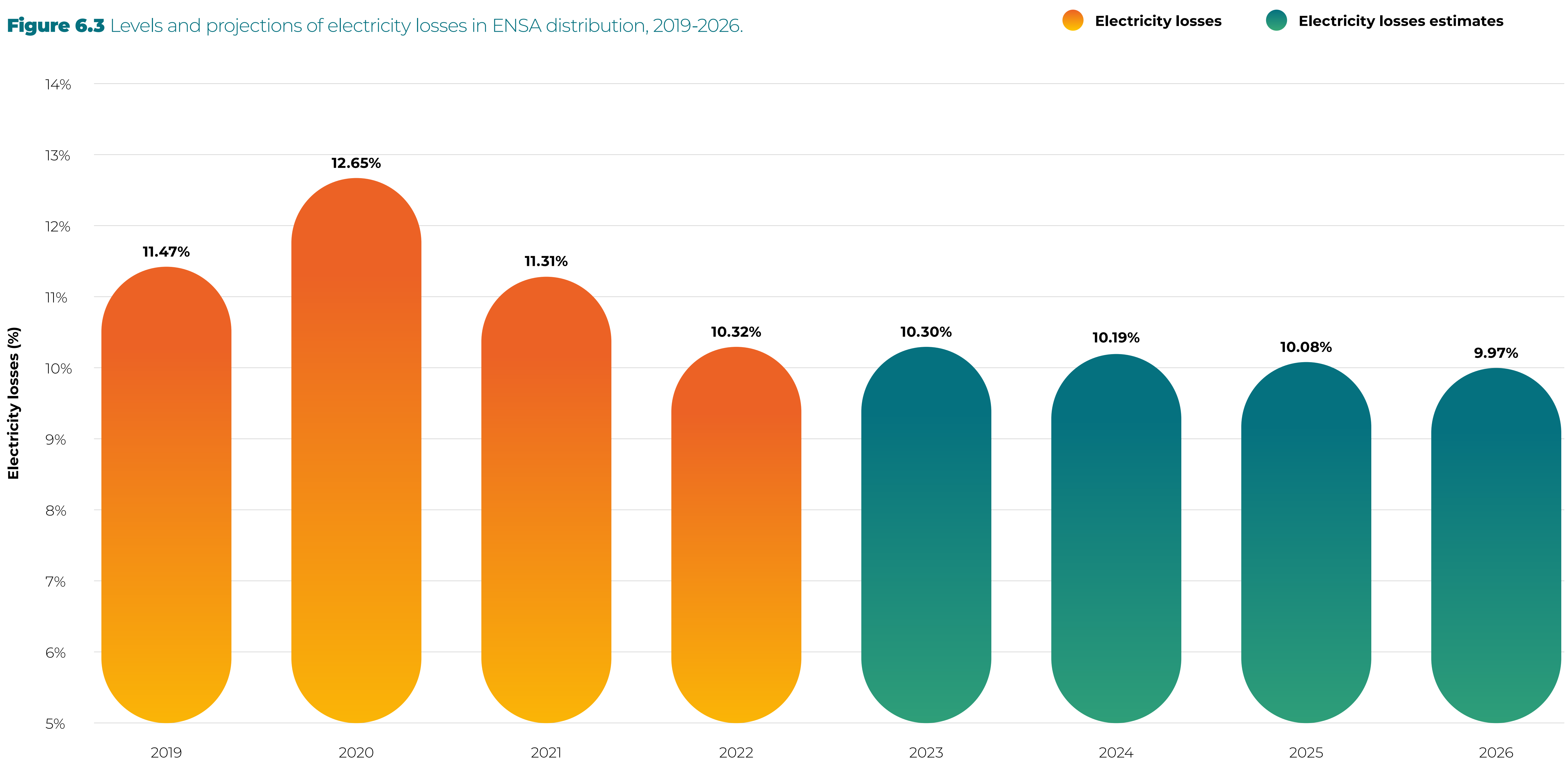
The objective of the strategy developed to reduce and manage losses is to minimize the susceptibility of the infrastructure to fraudulent activities and provide a practical alternative for supply to illegal users. This strategy encompasses the following measures:

1. **Expansion and improvement of the distribution grids.** This includes investments to expand and improve connections, which are expected to maintain an adequate quality of electrical services for all users. As discussed in Chapter 4, the quality of electrical services is closely linked to the level of electricity loss.

2. **Smart and prepaid meters.** The company hopes to continue expanding this measurement technology as part of its plan to modernize its distribution network. Smart metering refers to equipment that can communicate through supervision, control, and data acquisition systems/programs to clients with a demand of more than 100 kW. In the case of prepaid meters, the company is also making an intensive investment in their installation as part of its strategy to reduce non-technical losses while promoting the efficient use of energy and reducing the percentage of delinquencies. As of 2022, the company has 7,757 smart meters that report data to the control center and has added 22,498 customers to the energy service in prepaid mode.

3. **Improvements in technology and innovation.** The company plans to digitalize its electrical power grid to achieve a more efficient network with greater control over service payments. In the operationalization of the digitalisation of the electric power system, we can highlight a greater number of inspections carried out with new machine-learning techniques and the implementation of a new logical neighborhood model.

Figure 6.3 Levels and projections of electricity losses in ENSA distribution, 2019-2026.



Source: Prepared by the authors based on ENSA sustainability reports and information provided by the company. The percentage of losses takes into account sales to large customers.

AIR-E S.A.S. E.S.P., Colombia[54]

Electricaribe (ECA), a Colombian electricity distribution and commercialization company, faced a scenario where it could not ensure a continuous, high-quality supply for its end users as a service provider. This situation was due to several adverse factors, including weak infrastructure, frequent service interruptions, and an imminent financial crisis. Faced with this problem, the Superintendency of Home Public Services of Colombia (SSPD) decided to intervene and began a process of involving investors to reassign the operation of the Local Distribution, Regional Transmission, and Commercialization of Electric Energy Systems served by ECA in the departments of Atlántico, Bolívar, Córdoba, Cesar, La Guajira, Magdalena, and Sucre. As a result of this process, the ECA market was divided into two geographical areas: CaribeSol, comprising Atlántico, La Guajira, and Magdalena; and CaribeMar, comprising Bolívar, Cesar, Córdoba, and Sucre.

In March 2020, as a result of implementing the business solution, the energy market of CaribeSol for distribution and commercialization was awarded to the consortium "Energía de la Costa", comprised of Latin American Capital Corp and Empresa de Energía de Pereira. This market was to be operated by the company Caribesol de la Costa S.A.S. E.S.P., which is known today as AIR-E S.A.S. E.S.P. (AIR-E).

AIR-E began operations on October 1st, thus guaranteeing continuity in the provision of electrical service in the Caribbean region in the departments of Atlántico, Magdalena, and La Guajira on the northern coast of Colombia, providing service to approximately 1.25 million users in 2021. Within the socio-demographic statistics of the area operated by AIR-E, 73% of its users belong to the lowest income strata, identified as strata 1–3 in the country's electricity service rate system. Given the economic vulnerability of these users, they receive subsidies that cover 15%–60% of the unit cost of electricity. Of these users, 94% were residential customers, and 90% were located in urban areas.

In accordance with the provisions of the National Development Plan (Law 1955 of 2019), the SSPD and AIR-E agreed to subscribe to a Long-Term Management Program (PGLP) with a particular focus on investments and improvement in the provision of electrical services for a period of five years, from January 1st, 2021, to December 31st, 2025. This program includes the reduction of losses and improvement in the continuity and reliability of the electrical service among its main goals. To meet these objectives, the AIR-E plans to make a series of investments for 2021–2025[55] to guarantee the provision of an efficient, high-quality, and sustainable service in the long term. The main objectives of the five-year investment plan to reduce electricity losses and increase service quality are as follows:

54. This case study was prepared from reports from the Superintendency of Home Public Services of Colombia (SSPD), the 2021 Integrated Management Report, the investment plan execution reports and information provided by the company.
55. The total amount of the investment projected by Aire is close to COP 2.4 billion, equivalent to approximately USD 500 million. IDB Group, through 1.6 IDB Invest, will provide a corporate loan for an amount of up to COP 180,000 million. With these resources, the company will be able to carry out its 2021–2025 five-year investment plan.

Reduction of technical and non-technical losses

AIR-E identified the causes of non-technical losses, accepting the challenge of operating in low-income regions with extensive social and economic problems. These factors encourage illegal connections, fraud, and tampering with measurement systems. Similarly, several communities of electricity consumers in the Caribbean have developed a subculture of nonpayment and fraud. The company has also recognized that ineffective monitoring and insufficient investment in management systems can aggravate this problem. Based on this diagnosis, AIR-E developed a strategy to reduce the rate of losses or energy to be recovered, which makes it possible to define and prioritize investments in the Comprehensive Loss Plan for the five-year period from 2021 to 2025.

The investments made by AIR-E to reduce non-technical losses have focused mainly on the replacement of obsolete equipment, network assurance, and the integration of technological improvements in measurement systems. These measures allow centralized, real-time monitoring of the electrical grid. The technological upgrading strategy supports AIR-E's efforts to combat service-related fraud and delinquency. The specific strategy to reduce non-technical losses includes the following activities:

1. Strengthening measurement control: Special management vis-à-vis large consumers, aimed at achieving 100% remotely metered users during the first years of investment.
2. Introducing technical and technological anti-fraud advances to the grid and measurement, including installing protected grids and advanced measurement smart meters.
3. Promoting measurement and prepayment technologies in neighborhoods that are difficult to manage.
4. Incorporating information systems that integrate measurement technologies with the energy collection and control cycle.
5. Normalizing unmetered users.
6. Implementing communication, cultural change, social management actions, and technological strategies.

AIR-E developed a strategy to reduce the rate of losses or energy to be recovered, which makes it possible to define and prioritize the investments of the Comprehensive Loss Plan for the 2021–2025 five-year period.

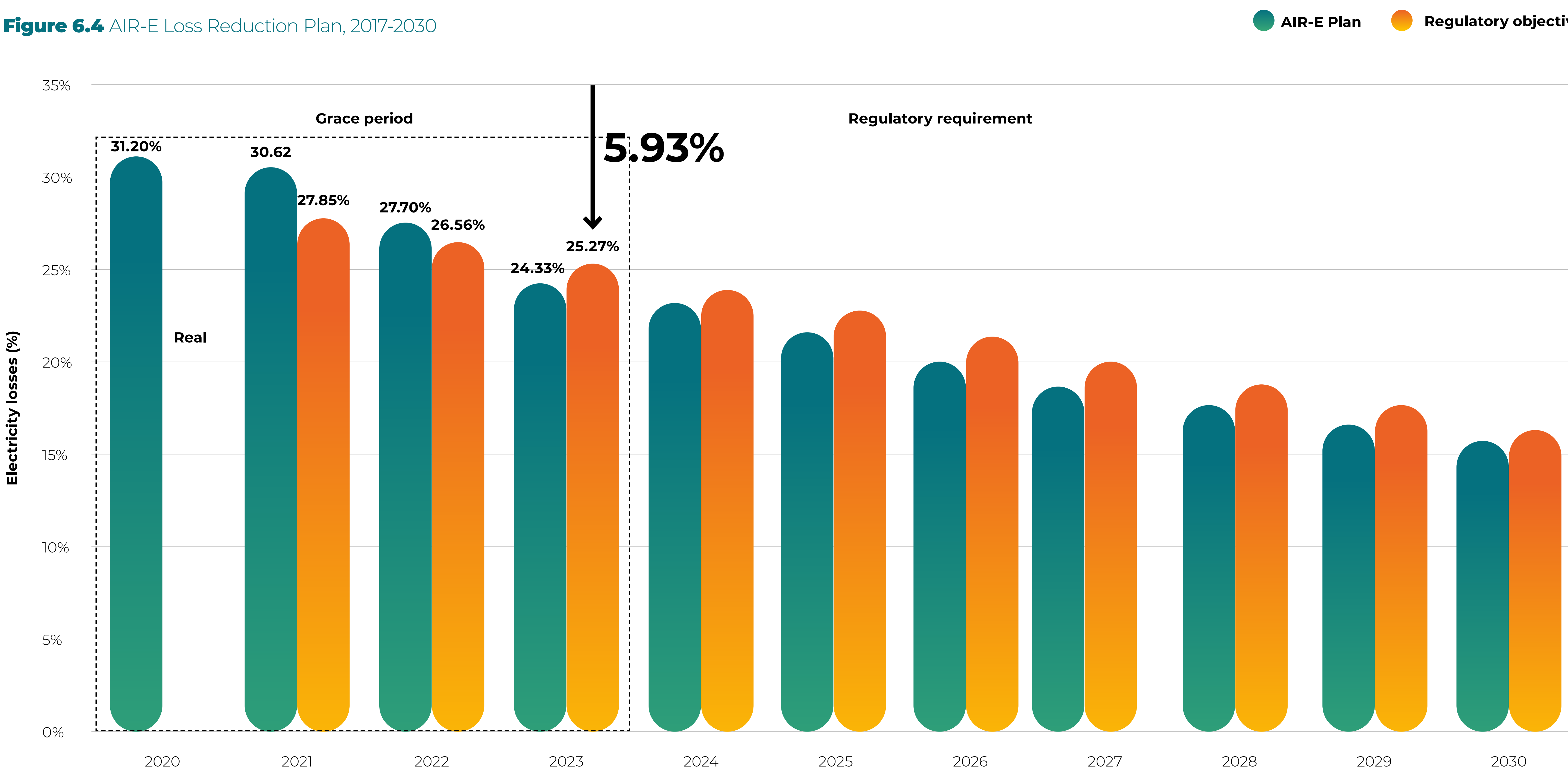
AIR-E's Strategic Information Technology Plan (PETI) plays a crucial role in the implementation of technological innovations and system modernization. This plan is based on five pillars: technological simplicity, cost efficiency, operational excellence, risk management, and digital transformation.

Regarding investments for reducing technical losses, these are directed at the modernization and strengthening of the service infrastructure, the renewal, and modernization of equipment in substations, the installation, improvement, and replacement of new grids, and the renewal of high and medium voltage grids.

AIR-E's Strategic Information Technology Plan (PETI) plays a crucial role in the implementation of technological innovations and modernization of systems. This plan is based on five main pillars: technological simplicity, cost efficiency, operational excellence, risk management, and digital transformation. To achieve the stated objectives, different projects have been aligned with the strategic initiatives defined in the PETI. This was carried out through a migration plan to modernize applications and implement cutting-edge infrastructure hosted in an ICREA IV-certified data center. In addition, the entire process is supported by effective change management. In 2021, as part of this plan, key projects were implemented to renew the technological and telecommunications infrastructure and the transition of "core" applications from the Shared Services Center (CSC) to their own systems, guaranteeing operational continuity. This included entry into the production of critical systems such as the Commercial Information System (CIS), Data Control and Analysis System (SCADA), Geographic Information System (GIS), and Enterprise Revenue Control System (ERP).

Figure 6.4 compares the loss reduction plan defined by the regulator with the objectives established by the AIR-E. At the end of 2020, AIR-E's loss level was 31%, in contrast to the national average of 14%. However, the aforementioned actions managed to reduce losses to 27.8% in 2022, thus meeting the grace period requirements set by the regulator. As part of its objectives, AIR-E plans to reduce loss levels to 24% by 2025 and to levels close to 15% by 2030.

Figure 6.4 AIR-E Loss Reduction Plan, 2017-2030



Source: Based on information provided by AIR-E.

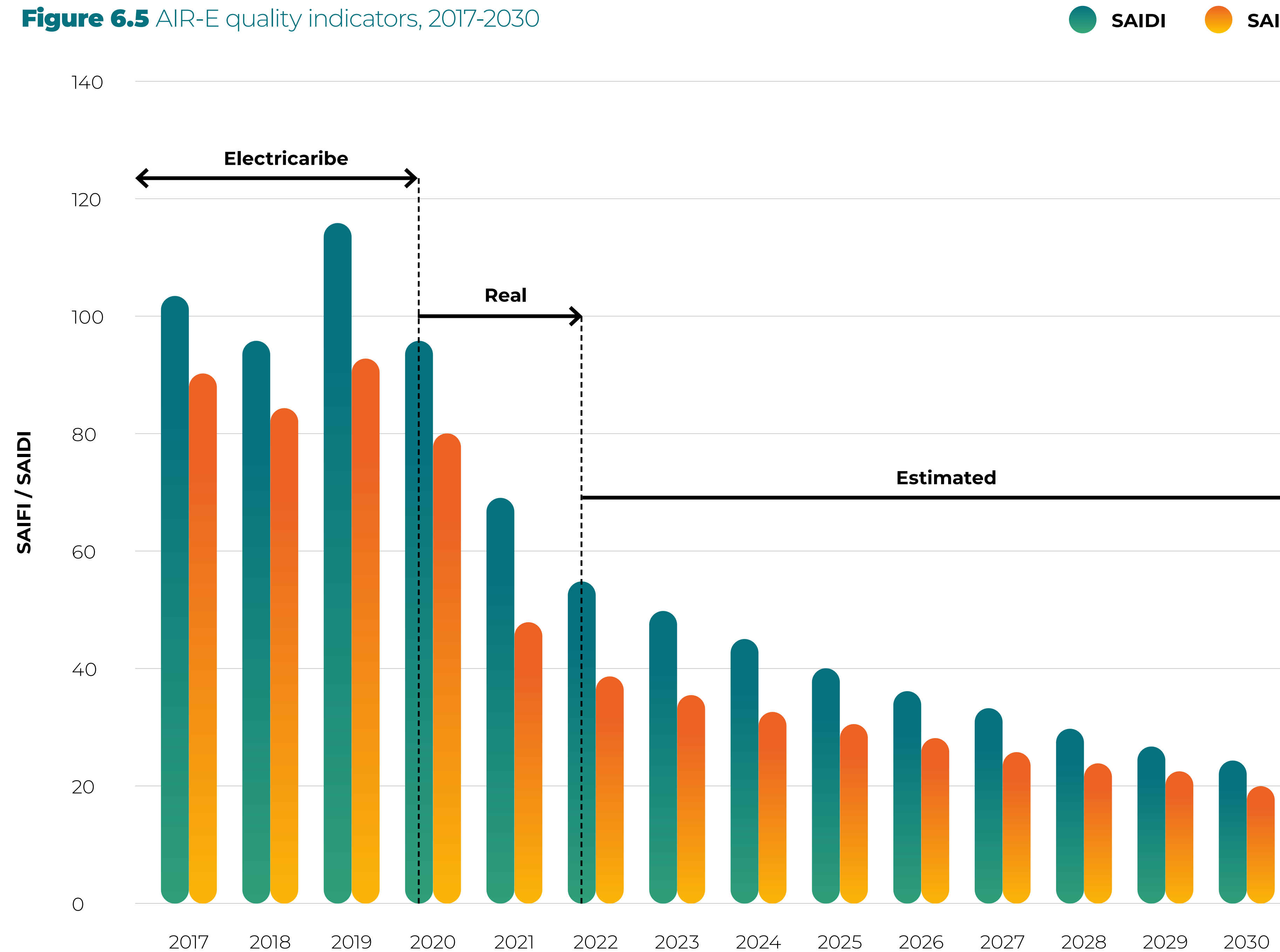
Increase in quality of service

In 2019, users within the AIR-E coverage area experienced an average of 93 interruptions (SAIFI) and 115 average hours of service interruption (SAIDI) per year, equivalent to approximately five days per year without service (see Figure 6.5). By then, the low quality of the service resulted in constant protests and demonstrations by users, leading to public disturbances. Likewise, in retaliation for the poor quality of the service, users did not pay their bills and were illegally connected to the network. This situation has had a further negative impact on the competitiveness and costs of electric utility companies.

By 2022, the SAIDI and SAIFI indicators showed marked improvements, even exceeding the regulatory goals established for 2025, although the quality of service is still not at the national average. With a result of a SAIDI of 51.78 hours and a SAIFI of 34.84 events by the end of December 2022, Air-e would have achieved a reduction of 55% and 62%, respectively, with respect to the SAIDI and SAIFI values of 2019. These operating results are possible because of the successful execution of the investment plan since 2021.

Among the plan's success factors is the regulated nature of the distribution business, which provides stability and predictability for a company's revenue stream. Colombia's solid regulatory and institutional framework has generated adequate incentives to improve its electrical infrastructure.

Figure 6.5 AIR-E quality indicators, 2017-2030



Source: Based on information provided by AIR-E.
Nota: The SAIDI indicator represents the average number of hours during which the service is interrupted, while SAIFI refers to the annual average of service interruptions.

ENEL[56]

Enel is a noteworthy exception in the region, where numerous companies lack the financial resources and capital necessary to adopt and implement emerging innovations in the electrical distribution sector. This company, identified as a leading entity worldwide, manages its electrical networks through its business line, "Enel Grids." In Latin America and the Caribbean, it supplies electricity to Argentina, Brazil, Colombia, Peru, Costa Rica, Guatemala, and Panama. The company has introduced "Grid Futurability," a global approach that embodies a strategic vision combining technologies to optimize the use of existing electrical networks and build fully digital smart grids. Among its notable projects is "Grid Blue Sky," a unified operational model aimed at optimizing energy distribution based on standardized processes, organizational structures, and a cohesive technological platform, all directed at improving the quality of the service provided.

This model includes the operation of repositories for 3D modeling of the HV/MV/LV grids, including data from inspections carried out on the grid (anomalies, clouds, points, photographs, videos, etc.). Drones and ground equipment are used to collect information from HV/MV/LV transmission lines. Terrestrial laser scanners (TLS) are used through comprehensive digital mobile mapping for HV/HV, HV/MV, and MV/LV substation/stations. This methodology optimizes inspections and checks on power lines and substations, reducing field visits and allowing for virtual inspections, resulting in organizational and process benefits.

In addition, it includes the implementation of SWiM, a Grid Blue Sky module, which improves maintenance management through a web application that includes a global catalog of anomalies and activities. This module prioritizes grid care tasks based on the severity of the defects found and their probability of occurrence according to a risk matrix associated with each defect detected in the grid.

Enel has also opted for the development of new technological tools such as Quantum Edge to digitize secondary cabins or the Network Digital Twin.

1. The Quantum Edge device is an all-in-one tool that enables distribution system operators to manage the increasing complexity of power flows more efficiently. Quantum Edge is responsible for basic and advanced measurement and monitoring of LV and MV grids due to its decentralized computing capacity and multipurpose platform. In addition, it makes it possible to reduce the amount of equipment in the secondary substation owing to the possibility of virtualizing key grid automation functions through customizable applications.

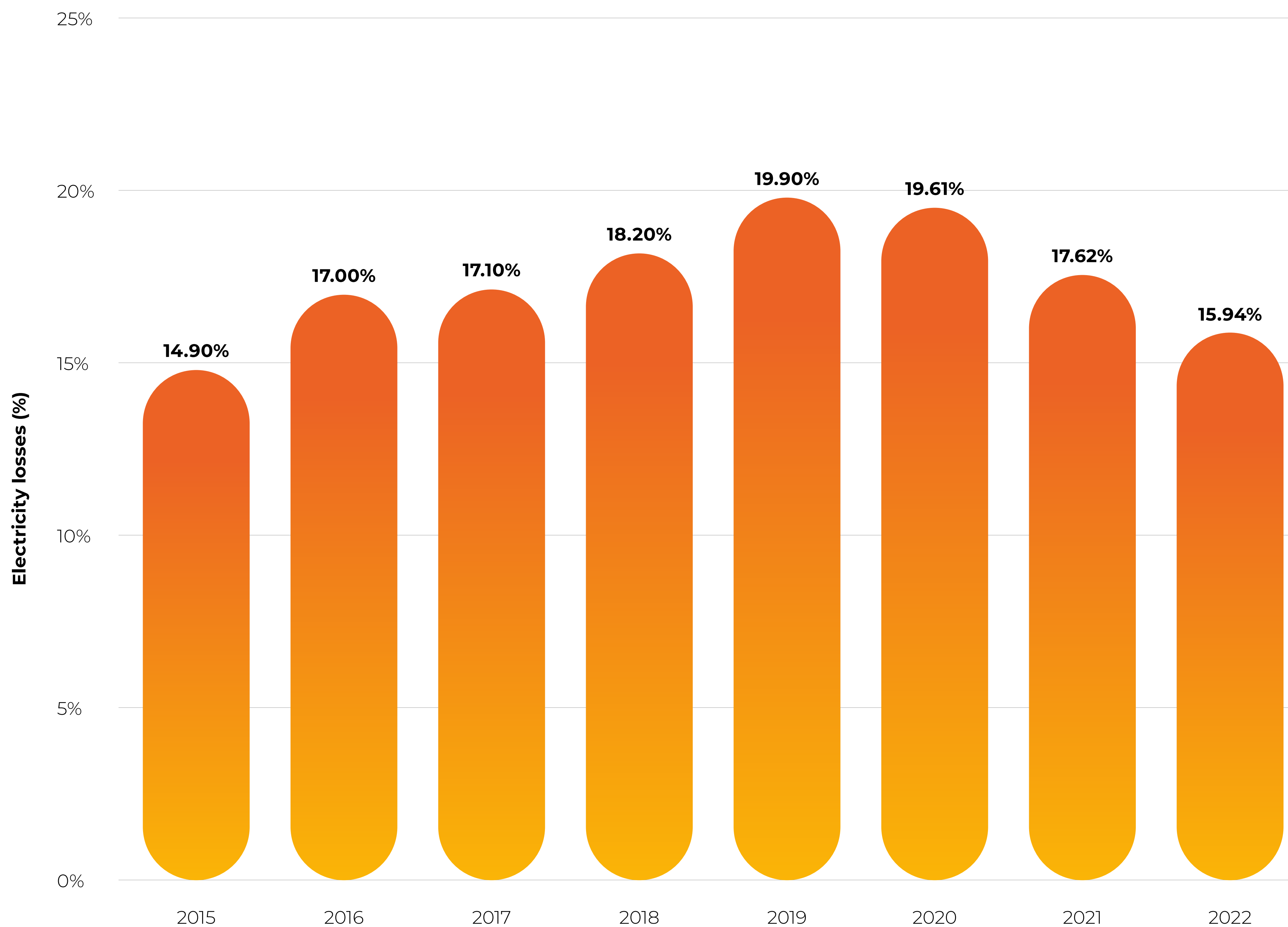
2. The Network Digital Twin replicates the entire electrical infrastructure using a 3D model, allowing for simulations and predictive maintenance using machine learning algorithms. AI is used to process data from sensors installed on the grid and cameras installed on drones, providing a global view of the state of the grid for timely inspection and intervention decisions.

56. Based on annual reports from Enel Chile, Peru, and Argentina, as well as sustainability reports from these companies.

Edenor Case – Argentina[57]

Edenor is one of the main electricity suppliers in Argentina, operating primarily in the metropolitan area of Buenos Aires. One of the companies' most critical problems is the management of electricity losses. Historically, the loss indicator has shown an upward trend (see Figure 6.6). In 2017, the company's losses amounted to 17.1%, which exceeded the regulated percentage by approximately 7%. This excess amounted to nearly USD 4 billion in unrealized income. The losses incurred in 2019 represented the highest point in the past decade, underscoring the pressing need for effective management in this area. This situation has prompted the company to implement a series of strategies aimed at mitigating this problem. One of these measures includes investment in smart meters, which allow for more precise and efficient monitoring of electricity consumption.

Figure 6.6 Total EDENOR electricity losses, 2017-2022



Source: Prepared by the authors based on EDENOR annual reports.

57. Based on EDENOR annual reports from 2017, 2018, 2019, 2020, 2021 and 2022.

One of the strategies adopted by Edenor to mitigate the problem of electricity losses has been to identify the regions with the greatest presence of irregular settlements and the highest rates of electricity theft and to focus its efforts on these. The company recognized that energy theft in these areas represents the main challenge in loss management. Among the company's most significant actions is the acceleration of the installation of Integrated Energy Meters (IEMs) and intelligent devices designed to improve the monitoring of electricity consumption. In 2017, Edenor launched a plan to install 250,000 IEM meters over the following years. In 2017, 48,560 IEMs were installed, and the remaining meters were scheduled for installation in the subsequent years. As of 2022, 237,736 IEM meters were installed. This plan is designed with the objective of regularizing the situation of clandestine clients, inactive clients, and those with chronic debt. These prepaid meters are pre-loaded with 150 kW and allow people with an irregular income to recharge their meters at the lowest rate, known as the subsidized rate, while allowing self-management of energy consumption.

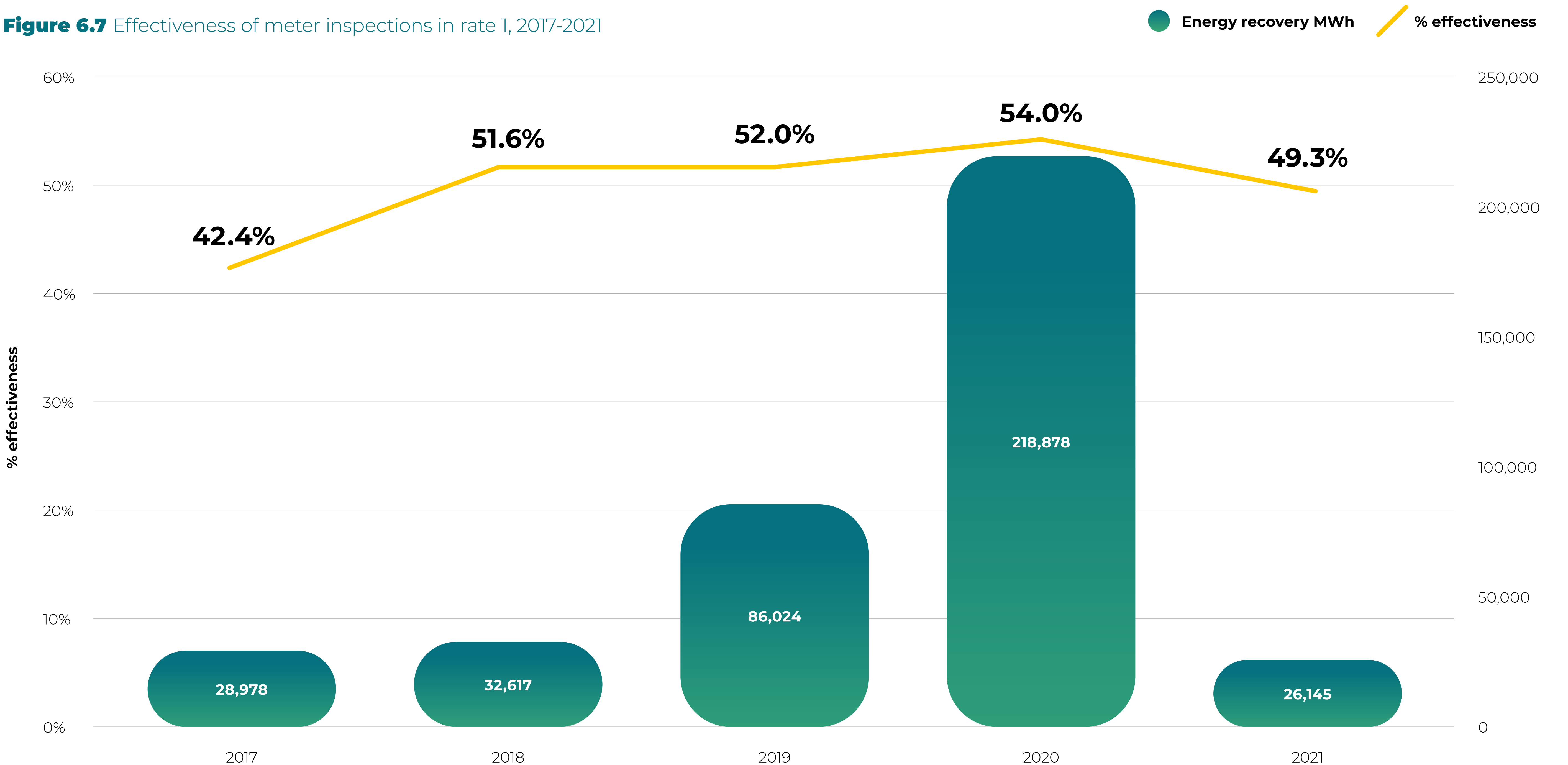
Additionally, 314 new smart meter concentrators were implemented in 2022, bringing the total of these devices in Edenor's infrastructure to 686. These installations provide daily information on approximately 73,000 meters, thus facilitating better inspection guidance and optimizing the company's operational efficiency.

Since 2018, Edenor has implemented an innovative grid called Multiple Concentrics (MULCON) that optimizes the functionalities of the IEM meter and enhances its resistance to fraudulent tampering. Given the effectiveness of this system, the company has begun to implement it in neighborhoods with a high incidence of fraud.

The company has also intensified the development of analytical and artificial intelligence tools to improve their effectiveness in identifying and managing inspections aimed at reducing energy theft. This investment in technology has provided tangible results; the effectiveness of inspections carried out on meters at rate 1 (small demand) increased from 42.4% in 2017 to 54% in 2020. Simultaneously, the amount of unbilled energy recovered from clients with fraud or technical anomalies increased from 29,000 MWh in 2017 to 218,000 MWh in 2020 (See Figure 6.7). In 2021, however, certain regulatory changes impacted Edenor's energy recovery strategy, demonstrating that managing energy losses is also subject to external and regulatory factors, requiring constant adaptations and updates in company management.

Recently, Edenor introduced in Rate 2 (corresponding to medium demands) a remote management plan involving the technological replacement of 1,650 meters. This significant advancement enabled the company to remotely supervise 10.5% of the energy supplied in the T2 category by 2022. This implementation represents a qualitative leap in the management and control of electrical supply, providing greater efficiency and precision to the company's processes.

Figure 6.7 Effectiveness of meter inspections in rate 1, 2017-2021



Source: Prepared by the authors based on EDENOR annual reports.

Note: The effectiveness of electrical inspections refers to the ability and accuracy with which these reviews detect and report anomalies or problems within the electric power system. It is measured by the percentage of inspections that result in significant findings compared to the total number of inspections carried out.

The measures undertaken in the field, together with the implementation of technological innovations such as IEM meters, have made it possible to reverse the growing trend in energy losses that had been observed in recent years, even in a context of electricity rate increases. However, despite these advances, the problem of electricity losses persists, and recurrence of electrical fraud stands as one of the main challenges to overcome. The future of loss management at Edenor will therefore require even more effective and adaptive strategies to address this persistent problem.

6.4 Conclusions

In the last decade, the energy sector has witnessed an unprecedented technological transformation, presenting cost-effective solutions to challenges such as electricity losses. However, there is still a long way to go along the path toward total digitalisation and the optimized use of these technologies to minimize losses. The digitalisation process has advanced moderately in the LAC, confronting significant investment needs. In this scenario, the private sector emerges not only as a catalyst but also as an indispensable strategic partner in the modernization of the electricity sector.

It is estimated that Latin America and the Caribbean will require almost four times the current investment in the distribution and storage sectors over the next decade. In the face of growing fiscal tension, the private sector's contribution is essential for mobilizing resources and adopting new technologies. The International Energy Agency predicts that the majority of funding, approximately 70%, needed to fulfill the net-zero scenario objectives in the region will come from private sources. These findings emphasize the significance of private sector initiatives in modernizing and digitizing electrical grids. Notably, this modernization process aims to tackle the issue of electricity losses while also aligning with global climate objectives.

Beyond capital mobilization, regulatory and market conditions are crucial to establishing efficient and transparent mechanisms for recovering investments and encouraging the adoption of new technologies. These conditions must ensure that the prospect of investing in long-term assets is attractive, and its associated risks are mitigated. This configuration is key to accelerating the adoption of advanced technological solutions for electrical distribution systems.

The case studies analyzed in the region highlight the commitment to modernization and innovation despite the varied contexts in which they operate. Key factors facilitating this transition include scalability, robustness, and relevance of the new technologies adopted by these companies. These technological features minimize associated risks and simplify implementation. However, these technological initiatives must be complemented by an appropriate institutional environment that offers clear rules and allows investment recovery. Notably, some technologies that have already proven effective and are gaining popularity in the region include smart meters and prepaid systems. Additionally, the private sector's financial capacity is crucial in advancing these initiatives. However, this was not an absolute rule. There are cases in which a lack of financing has limited the ability of companies to carry out their investment plans, perpetuating a cycle of high losses and low quality of service. The participation of Multilateral Development Banks such as the IDB is crucial to help companies in the region break this cycle of underinvestment.

Chapter 7

Costs and benefits of reducing electricity losses

In the previous chapters, we discussed the complexity that characterizes electricity losses and their magnitude and persistence over time in Latin America and the Caribbean. Chapters 5 and 6 addressed experiences at the country and electric utility company levels, where different degrees of progress have been achieved in reducing technical and non-technical losses despite some difficulties. This chapter aims to establish the net economic benefit of a policy to reduce electricity losses, viewed from a cost-benefit analysis approach.

Economic profitability — including both financial and social net benefits — is a crucial element that guides investment decisions in electrical systems. Generally, estimating this profitability is a necessary condition when making public investments. In this regard, it should be noted that this analytical approach and the estimation of such profitability can be sensitive to the characteristics of the area under consideration, to the main reasons underlying the losses, and to the regulatory framework in which the companies operate. For example, technical and non-technical losses may have different treatments that affect the extent of expected benefits. Likewise, schemes in which losses above the regulatory limits are allowed to be transferred to end-user rates can affect the behavior of demand and, therefore, the net benefits of loss control and reduction measures.

This chapter provides an analytical review of the costs and benefits associated with non-technical loss reduction interventions and then presents an added exercise that simulates the effects that could be expected when implementing a policy that aims to achieve efficient loss levels. The analysis is based on empirical regularities observed in the region's electric power systems, including the persistence of loss levels, their main sources, and their financial and environmental costs. We also take into account the investments required and the maturation time to achieve the expected impacts.

The chapter begins by differentiating the object of analysis between technical and non-technical losses. Although in terms of investment, both are closely linked— typically, the reduction of commercial losses involves associated investments in transmission, sub-transmission, and distribution grids, which also reduce technical losses—the social implications of reducing each type of loss are different. Interventions to mitigate technical losses fully increase the system's efficiency by reducing energy losses that any user does not consume. On the other hand, commercial losses generally involve normalizing situations in which users consume energy that is not measured or billed by electric utility companies.

The analysis is based on data from official sources and previous experiences of loss control and reduction programs in both public and private companies. It draws on expert opinions to establish appropriate and conservative assumptions. The results can be taken as a baseline regarding a loss reduction policy's potential aggregate net effect. However, specific cases may present significant divergences owing to particularities that tend to influence the effectiveness of loss reduction measures, their control, and the potential benefits that can be achieved.

7.1 Benefits of reducing non-technical losses

From the point of view of electric utility companies, electricity losses for commercial reasons impose costs that are similar to technical losses. However, investments to control and reduce them have different implications. In the case of technical losses, investments are mainly allocated to the improvement or expansion of energy transportation systems that typically involve improvements in the efficiency of electric power systems. On the other hand, investments specifically aimed at controlling commercial losses may also include everything from subsidy programs, supervision campaigns, to investment programs in grid expansion and installation of meters to normalize irregularly connected users. With everything else remaining constant, and in a very simplified way, the reduction of technical losses entails energy savings, while the reduction of commercial losses implies a recovery of resources. In this sense, the reduction of commercial losses would imply a redistribution of the profits from the energy delivered.

Thus, we would like to highlight that commercial losses constitute an organic part of the energy demand of system users (homes or companies). This refers to energy consumption that yields some benefit to them. It is also noteworthy that, to the extent that this consumption originates from a group of users who are not subject to adequate measurement or who do not pay at all for the energy consumed, excess demand can occur, reflecting inefficient energy consumption. Indeed, the effect on consumption will depend on the characteristics of the population where this problem occurs (see Box 7.1). This means that these users do not assume the rates that correspond to the generation, transportation, and distribution of energy, leading to losses of social well-being. In general, this type of loss can have the following effects:

A **They increase the cost of providing services to customers.** In electricity markets, this can happen in two ways. On the one hand, and to the extent that electricity rates recognize a portion of electricity losses, these costs can be transferred to customers via prices, reducing their surplus welfare. On the other hand, it could occur through the incremental costs of generating the electric power necessary to meet the additional demand represented by the losses. These additional generation costs must also be transferred to rates, increasing the cost of service to end consumers. Note that this effect would not only be due to the cost of generation and starting up higher-cost plants per additional MWh, but also to the investment costs that could arise from meeting excessive demand due to the presence of electricity losses. The alternative case of service rationing has other types of effects that will be discussed below.

B **They produce financial losses in the electric power system.** Losses not recognized by the regulator (via rates) have to be absorbed by the electric utility company. This reduces their income, which in turn weakens their financial position and their ability to invest in the medium and long term. Even when the financial losses of electric utility companies can be covered—partially—by the treasury through transfers from the State, they still represent a monetary loss for society..

C **They increase greenhouse gas (GHG) emissions as a result of overconsumption of energy.** As already mentioned, unmetered and unbilled energy use can be expected to lead to inefficient use of electric services. To what extent an inefficient use of electricity will translate into an environmental extra cost will depend on the size of the carbon footprint of the electricity generation park.[58] It is worth remembering here that the environmental impact of electricity losses in LAC is substantial, as shown in Chapter 3.

An effect that is more difficult to quantify, but equally relevant, has to do with the welfare losses of users as a result of a reduced quality in the provision of electric service. Indeed, a characteristic of systems with high levels of electricity losses is that the services they provide are of low quality, which is mainly manifested in a high number of electrical interruptions and voltage instabilities. This low quality of service can originate from the deficit of investment in infrastructure and/or in electricity rationing measures[59] by electric utility companies as a mitigation mechanism to reduce the levels of losses they experience. Companies also use electrical rationing measures with the central objective of preventing/minimizing the system from becoming saturated and outages occurring due to system failures. In general, regardless of the objective of rationing, the adjustment that occurs in this case is not by price (as discussed in item (a)), but by quantity. In this context, the cost is very high, including the willingness to pay for energy not produced, plus the economic losses associated with power outages for unproduced or wasted goods and services. Thus, loss reduction programs generally lead to improvements in the quality of the services provided. This situation has been documented in countries such as Ecuador and the Dominican Republic, where commercial loss reduction programs led to the normalization of users and the improvement of their electric services, which in turn increased their electricity consumption (Jiménez Mori, 2018; Jiménez Mori and Yépez-García, 2020). To the extent that information is available, improvements in user well-being as a result of improvements in service quality can be considered—and quantified—as a benefit of loss control and reduction programs. Among the impacts on the well-being of users is not only the convenience of increasing service reliability, but even indirect positive effects on educational results in children and increasing the productivity of companies and their income levels (see Box 7.2).

58. Depending on the amount of energy that needs to be “replenished” and the technology used to respond at the margin, the carbon footprint attributable to inefficiency losses may have a higher carbon load than the average mix

59. For example, the so-called *rolling blackouts.*

Box 7.1
Context matters in understanding benefit

Understanding the composition and characteristics of the users that will be affected by the loss reduction policy is essential when outlining its potential benefits. For example, the income or socioeconomic level of informally connected users will contain information about their degree of vulnerability, but also about their probable energy consumption patterns. It is likely that vulnerable households will not overconsume, even with a 0 rate, since they have a limited number of electrical devices at home. The situation is different in homes of other socioeconomic levels or established firms.

Analyzing the impacts of a loss reduction policy therefore leads to understanding and discussing its distributional implications. Even in the case where one segment of users pays for the losses caused by another segment of (irregular) users, there may be consequences for the aggregate well-being. For example, if irregular users are a sufficiently large percentage and the price elasticity of demand for those who pay is high, there would be a significant change in the consumption of those who pay. However, it is not necessarily equivalent to transferring income from one group to another, with the aggregate amount consumed remaining constant. Elements such as the elasticity of demand of the different groups affected by the policy, their relative sizes and their uses of energy, are aspects to consider for a better understanding of the expected impacts.

Understanding the characteristics of users affected by loss reduction policies is crucial for determining their benefits. The analysis should consider distributive implications and demand elasticity among different user groups.

Box 7.2
Quality of electric services and user well-being

In many developing countries, unreliable electricity supplies are the rule rather than the exception. In these countries, public electricity services are highly rationed or have serious quality problems, and their rates are generally subsidized. These rates can even be kept below the cost of supplying the service (including the cost of generation plus transmission and distribution). The consequence of this practice is a deterioration in electric service reliability that imposes costs and inconveniences on consumers.

According to the specialized literature, the low quality of electricity service translates into loss of income for companies due to the underutilization of production capacity and inconvenience for households that cannot use the desired energy services (Steinbuks and Foster, 2010; Alby et al., 2013; Chakravorty et al., 2014; Fisher-Vanden et al., 2015; Allcott et al., 2016; Samad and Zhang, 2016; Falentina and Resosudarmo, 2019; Buenestado, 2020, and Oseni and Pollitt, 2015).

When electricity is an essential input for operation of a company, empirical evidence suggests that an unreliable supply can negatively affect its productivity. Allcott et al., (2016) analyzed the impact of electricity shortages caused by the seasonality of hydropower availability on large manufacturing companies in India. Their findings revealed that electricity shortages there reduced the average company's revenue by 5% to 10%. Grainger and Zhang (2019) did the same for Pakistani manufacturing companies. The authors estimated that an additional average daily hour of unexpected power outages decreases a company's annual revenue by 10%, and reduces its annual added value by 20%. These effects highlight the crucial role that access to reliable energy infrastructure plays in economic growth (Andersen and Dalgaard, 2013).

The opportunity cost of unsupplied electricity for companies can be measured through the value of lost production per kWh of unsupplied electricity. An accurate estimate of the opportunity cost requires access to the detailed operating accounts of businesses affected by service disruptions (as for example in Hashemi et al., 2018 for Nepal). When this information is not available, estimated willingness-to-pay (WTP) values can provide an approximation. By analyzing the relationship between estimated WTP and other observable characteristics of companies, we can better understand company decision-making when it comes to dealing with unreliable electricity supply.

For residential consumers, impacts on their well-being can be inferred from their willingness to pay for improvements in electrical services. Ozbafli and Jenkins (2016) used a choice experiment to assess the willingness of households to pay for better electricity services in Northern Cyprus. Their findings show that they are willing to pay premiums of 3.6% and 13.9% of their current electricity bills to obtain uninterrupted service for summer and winter, respectively. Likewise, Oseni (2017) estimates the WTP of a sample of Nigerian households for improved reliability of electricity supplied by the grid. The findings indicate that households are willing to pay more than their monthly bills for reliable service, and the WTP is significantly higher in households that have already adopted emergency diesel generators. In the Dominican Republic, Jiménez Mori (2018) shows that households at all income levels (informal or customers) and under different conditions of electric service give high ratings to improved services. Informal users show an average willingness to pay of around USD 9, while for formal users it represents 22% of their current electricity bill (USD 5 on average).

In turn, deficiencies in electrical services can have negative effects on the social and economic variables of households. In an analysis of impact evaluations carried out between 1980 and mid-2019, Jiménez Mori (2020) studied the effects of electrification on education, employment and income variables. The author identified effects of around 8% on school enrollment, 17% on employment and 24% on household income.

The willingness to pay (WTP) offers insight into the value that consumers and businesses place on reliable electricity supply. Various studies indicate that households are willing to pay additional amounts to ensure uninterrupted electrical service.

7.2 Who pays for electricity losses?

It is possible to outline two simplified schemes by which losses can be recognized in the rate structure. On the one extreme, all losses could be incorporated into rates, in which case customers who pay according to their consumption would assume the cost derived from users causing commercial losses. In a situation without rationing, assuming similar consumption patterns and elasticities, the net economic benefit of a loss-reduction policy would have distributional consequences. An alternative scenario is shown in Box 7.1.

On the other extreme, rather than being incorporated into rates, all losses would be absorbed by electric utility companies or by the state via subsidies. In this case, the added cost of energy losses could be considered as a transfer from one of these actors (the electric utility company and/or the state) to the end users.[60] In this scenario, direct losses for society would come mainly from the environmental cost of maintaining high levels of energy overconsumption.

An alternative situation would be one where the rates do not absorb all electricity losses but—as is common in Latin American electricity markets—only incorporate an efficient loss level. Thus, in cases where the actual loss levels exceed the efficiency levels, the company would be faced with an amount of energy supplied without compensation (losses above the efficiency levels). Consequently, unlike in the previous scenarios, the added monetary cost of electricity losses would be absorbed by both customers (who would have to pay a higher rate) and by financial losses for the electric utility company. In turn, society is harmed by excess consumption and the corresponding environmental costs.

In all cases, note that electric power rationing—whether as a result of infrastructure deficiencies or a strategy to reduce financial losses—would reduce the aggregate monetary cost of electricity losses. However, it would also negatively affect the well-being of consumers.

60. This produces distortions in the investment incentives for electric utility companies and/or consumes public resources with high opportunity costs, such as investments in public education and health. This last case emerges when losses are absorbed by the State (through subsidies or transfers to the company). In this case, the transfer is from users who do not pay for electricity to tax payers, who ultimately absorb the cost of the subsidy.

7.3 Cost-benefit analysis of electrical loss reduction at the user level

This exercise focuses on cases where non-commercial electricity losses are only partially transferred to the rates. No electricity rationing is assumed before the policy in estimating the net economic benefit. Under this baseline scenario, a simplified model is used to outline the effects of reducing electricity losses on social and environmental well-being. The starting point is a situation in which a segment of customers pays for the services they receive, while the other segment represents informal users who do not pay for their consumption. The latter are the recipients of the policy.

First, we start from a static scheme that allows us to qualitatively examine the effect on the well-being of the consumer, electric utility company, and society. Then, based on this framework, we simulate a scenario in which an effective loss-reduction policy is implemented in LAC countries.

Qualitative scheme of benefits and costs of electricity losses

Figure 7.1 summarizes the static case of a user responsible for commercial losses whose service is regularized, that is, who has an adequate connection and meter installed to bill their consumption, eliminating—or reducing to a minimum—their commercial losses. In this figure, the initial consumption point of those users responsible for commercial losses is (P0, Q0), representing a situation with low price and high consumption. After the normalization of the electric service received by the user, losses are recovered by moving the consumption to point (P1, Q1).

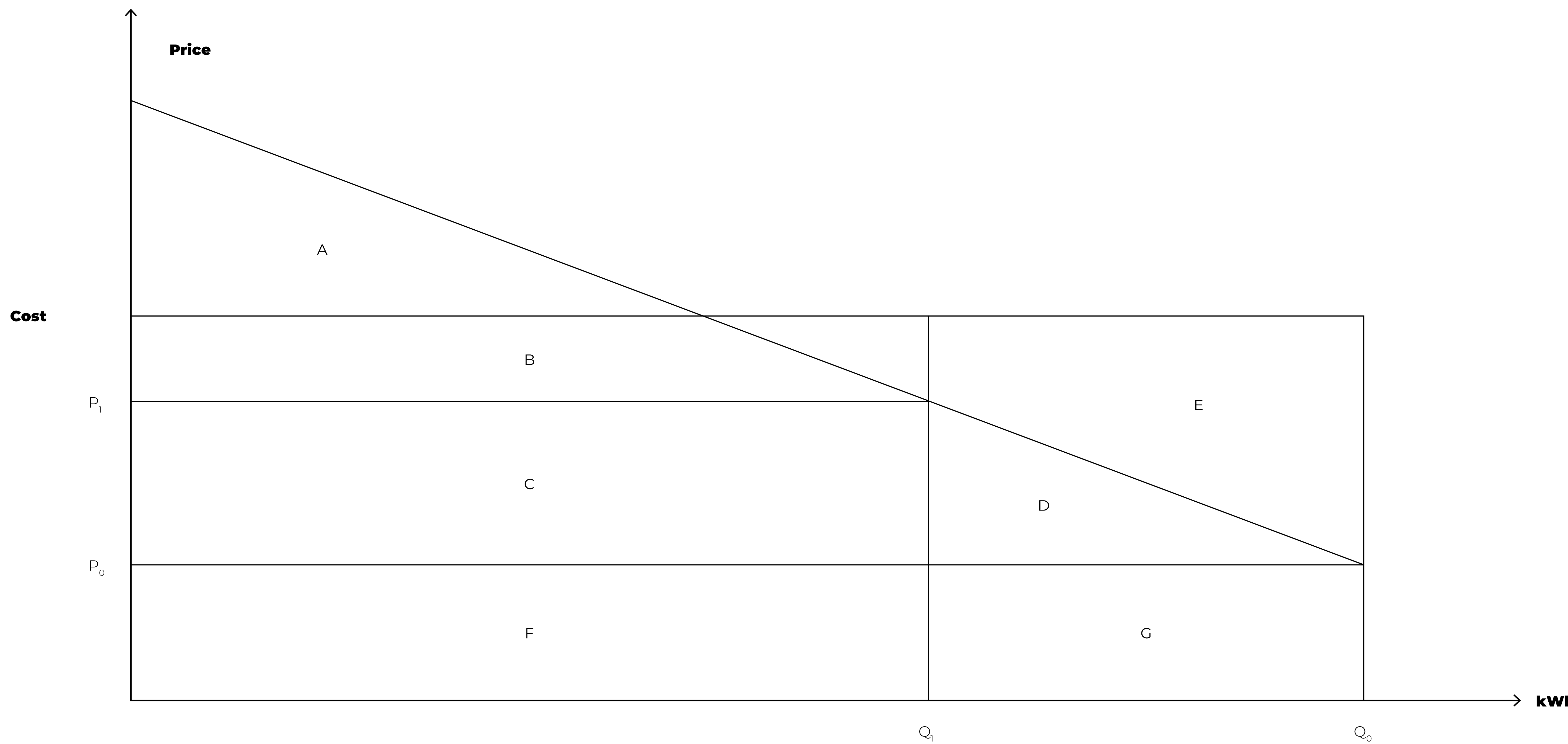
As a result of the loss reduction program: (i) consumer surplus is reduced by a value equal to area D, and (ii) the producer saves the entire cost of supplying consumption Q0 - Q1, equivalent to area E+D+G. Because the consumer was paying area G, the producer's savings were D+E. Consequently, the net welfare recovered is area E (D + E–D). This constitutes a net economic benefit to society owing to reduced losses.

Based on the discussion in the previous subsections, at least three observations can be made regarding this analysis: one of the distribution nature and another regarding environmental externalities. First, the analysis does not include distributional considerations beyond analyzing a case in which the population subject to the intervention would be subject to a price below the cost of the service. Situations, where the cost may be higher than the rate, are plausible because rate-block schemes are widely used in the region to contribute to the affordability of basic services.[61] Therefore, regardless of the relationship between the rate and cost of the service, under this scheme, the policy leads to a transfer of consumer surplus to pay for the service. Second, the analysis does not consider the potential benefits to the environment and the electricity generation system that may arise from the energy-saving effect. Such savings can occur when households previously unrestricted in their energy use begin to pay for their properly measured consumption. Depending on the magnitude of the savings, they can mean significant relief in terms of avoided emissions and for the generation park (delaying investments in generation and/or avoiding the startup of power plants with higher marginal costs). Third, the case analyzed does not involve rationing service provision before implementing the policy. If well-reasoned, the policy would typically involve an improvement in the service (measured) hat would generally lead to user welfare gains.[62]

On the other hand, from a financial point of view for the electric power system, areas D+E relate to savings due to lower consumption, while consumers now pay for area C, which they did not pay before. Therefore, the C + E + D area gives the financial benefit of loss reduction. These benefits are considered at the system level, and the particularities of policy implementation can become key to its effectiveness. A probable case is one in which the distribution company (not generation) is in charge of executing the investments associated with the loss reduction program and financing them. In such a case, regardless of the favorable economic and financial benefits at the system/society level, such a program must be profitable for the implementer. This is because, although (and as previously mentioned) the cost of the losses will be absorbed by some actors in society, in a functional system, its weight would fall mainly on utility companies, who in turn will be the implementers of the investments and responsible for their repayment. Therefore, another relevant dimension in the economic analysis of the loss reduction policy is the components that constitute the financial viability of the direct implementer who is responsible for the payment of investment resources. For example, Area C refers to the new direct monetary income that the company expects to receive. It would be interesting to examine its composition, magnitude, and time frame since it would obtain resources to repay investments.

61. There are no significant qualitative changes in the alternative of considering the cost to be below the rate. The aforementioned benefits are generated even when the supply cost is above the P1 rate.
62. Such improvements in service quality could also imply increases in energy consumption that reduce the expected potential savings. The net effect will depend on the context under analysis, both in terms of the characteristics of the services before and after the policy, as well as its target population.

Figure 7.1 Changes in surplus due to loss reduction measures



Source: Prepared by the authors

Regardless of the specificities that can be added to Diagram 7.1, this represents a widespread situation in the region. As shown in Chapter 3, of the 26 LAC countries, 23 present transmission and distribution losses above 10%, a level that can be considered high and originates, at least partially, from non-technical factors. In fact, several countries in the region regularly report levels of losses in the annual reports of their electric utility companies with different degrees of severity, which they attribute to non-technical causes to a greater or lesser extent. For example, in their 2020 report, the Federal Electricity Commission of Mexico (CFE) indicated that the main cause of the increase in the energy loss indicator is the existence of a greater theft of electric power, which amounts to 1350 GWh.

Consequently, it is reasonable to create a policy simulation aimed at achieving levels of electricity loss that can be considered closer to the reference standards. A scenario is then simulated in which losses are caused by informal users. The loss reduction policy, in this simplified case, takes the form of regularizing such users so that their electricity consumption becomes gradually billed.

One aspect to consider in the construction of this scenario is that we call the assumed intervention a policy. This is because, based on the performance of the region over the last five decades, it is evident that the issue of electricity losses is extremely complex and persistent, and reducing such losses requires planning and adoption of medium- and long-term measures. This implies the need to forge a commitment in different spheres so that those responsible for formulating policies achieve long-term objectives effectively and efficiently.

Simulation of the effects of an electrical loss reduction policy

The reference scenario is built on assumptions and parameters that reflect past experiences of loss reduction in the countries in the region as well as a conservative approach regarding costs and their potential benefits. The main assumptions are summarized as follows.

1. A target loss level of approximately 10% is assumed. To account for the geographic diversity and configurations of electric power systems in the region, this parameter (level of losses) was estimated as the average of the loss ratios of the countries with the lowest losses in each sub-region (Caribbean, Central America, Mexico, Southern Cone, and Andean Region).

   Efficient loss levels can certainly be lower. However, the assumed value allows us to partially account for the growing difficulty of addressing them owing to social factors that are beyond electric utility company management. The analysis thus admits the permanence of a level of loss beyond which further reductions may not be economically feasible when considering factors such as the existence of remote or socially complex geographic areas. See Box 7.2 for a brief discussion of the efficient loss levels.

2. For countries with loss ratios below the regional average, a policy implementation horizon (elimination of excess losses) of 10 years was assumed. For countries with loss ratios above average, a horizon of 20 years was assumed. Although the problem of electricity loss has shown notable persistence in LAC, there are notable cases from countries and electric utility companies that show that these horizons are reasonable and even relatively conservative, as seen in Chapter 5. Under these assumptions, the pace at which each country annually reduces its level of losses depends on the initial baseline, policy goal, and established horizon.

3. The cost of loss reduction is based on a survey of existing large-scale projects and expert opinions. A cost of USD 32.5 million per percentage point of loss reduction was assumed (in 2021 USD). While reduction costs can vary widely depending on factors such as the number of users to be normalized, the density of the area where they reside, their proximity to electric power systems, and the base infrastructure already established, the estimates proposed above are based on the upper limits.

It was assumed that investments in loss reduction were implemented progressively and reached their highest degree of execution in years 4–6. The investment profile varies among countries with different losses. It was also assumed that countries with low loss levels had already implemented base investments to initiate more focused phases of energy theft control. On the other hand, in countries with high levels, it was assumed that the investments to be made in the stages of identification, training of personnel, and basic infrastructure occurred in the first years and that those destined for control infrastructure then increased.

4. The simulation considers the growth rate in electricity demand per country by historical trends, economic prospects, and population density projections.[63]

5. A scenario without a project is assumed in which electricity losses remain around the average of the last five years.

63. The growth rates in electricity demand were taken from the analysis for Latin America and the Caribbean by Yépez García *et al.* (2018).

6 Electricity losses are valued at average rates for residential users in real terms in 2021. Based on expert opinions, conservative adjustments are made to these rates in contexts with high subsidies.

7 It is assumed that the energy consumption of regularized users exhibits a price elasticity of approximately -0.4%;[64] therefore, once recovered, the price effect will reduce new consumption. This reduction, in turn, considers the energy savings effect from the loss reduction policy. It is worth mentioning that the economic results vary drastically, depending on the assumed price elasticity. In general, the lower the elasticity, the greater the economic profit. Because the estimates for price elasticity usually lie within the range of -0.3 to -0.4, the central parameter assumed can be considered conservative.

8 Energy savings are transformed into avoided CO2 emissions based on the emission factor of each country's electrical grid as of 2021.[65]

9 Any avoided CO2 emissions are converted to monetary values using the social cost of carbon proposed by the Interagency Working Group on the Social Cost of Greenhouse Gases in the United States.

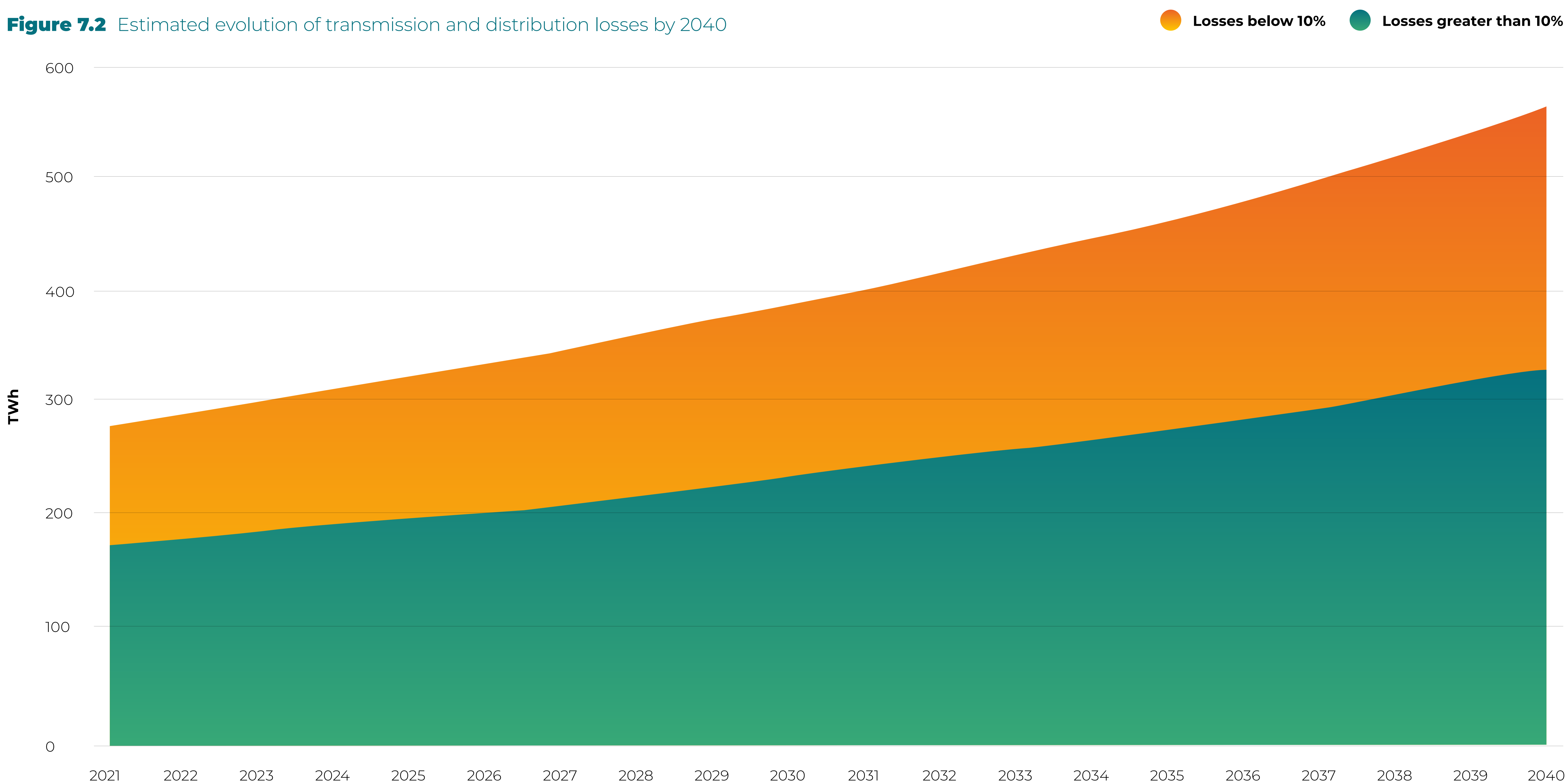
7.4 What trajectory would losses follow in a scenario without a policy?

Without an effective policy to reduce electricity losses, the exercise yields alarming figures for the future sustainability and efficiency of the electric power system. Figure 7.2 aggregates the losses in a scenario without loss reduction policies in the LAC. This graph indicates that over the next 20 years, an estimated 8,000 TWh of energy will be lost, with roughly 3,300 TWh of this amount representing losses exceeding 10%. These losses can be considered non-technical and may be economically viable to eliminate. In terms of the income that electric utility companies would fail to receive during the two decades forecast in the scenario used, these losses would represent close to USD 410 billion in financial losses (at 2021 prices). To provide a measure of this inefficient loss level (>10%), this represents approximately five times the net electricity generation of Latin America in 2019, while in monetary terms, it would turn out to be greater than Colombia's GDP in 2018 (298 billion in 2021 prices).

In this context, with the loss levels observed and forecasting derived from the performance of recent decades, the implementation of loss reduction policies represents a necessity, not an alternative. Such policies emerge as imperative to achieving a sustainable public service with quality levels appropriate for the population's growing demands. However, one of the most relevant aspects of implementing an investment program is that it must reduce losses and return sufficient economic benefits.

64. Studies covering a wide variety of systems find long-term elasticities in the order of -0.3 to -0.4. See Dahl (2011).
65. Version v.3.1 of the IFI Dataset of Default Grid Factors (IFI TWG, 2022).

Figure 7.2 Estimated evolution of transmission and distribution losses by 2040



Source: Prepared by the authors.

7.5 What are the costs and benefits of reducing electricity loss?

Based on the simulation exercise described above, the total (accumulated) investment required for the countries of the region to converge towards levels of electricity losses no greater than 10% within 20 years is estimated to be approximately USD 8.5 billion (in 2021 prices). This figure primarily reflects the total value of investments that would be used over decade-long investment horizons and, to a lesser extent, investments in loss control.

To be economically and socially viable, the investment required by the policy must exceed its expected benefits. That is, the expected benefits of this exercise (recovery of financial income for electric utility companies, energy savings, and emissions savings) must be sufficient in magnitude and occur promptly to compensate for the investments made appropriately. A standard measure for capturing the cost-benefit balance is the net present value of net benefits over the implementation horizon of this policy.

To consider the inter-temporal nature of these benefits, they are discounted at the investments' weighted average cost of capital (WACC) to obtain the net present value (NPV). Equivalently, the economic rate of return (ERR) implicit in the net benefit flows can also be compared with the WACC or the social discount rate to compare its attractiveness from the public policy perspective. Depending on the characteristics of the electric utility company implementing the policy, the two reference levels for these rates can be 5% and 12%.

Alternative scenarios are also proposed to consider higher growth paths for electricity demand and each policy's different degrees of effectiveness. The values of these parameters, in turn, respond to the interest in identifying inflection (or break-even) points that can serve as references for decision-makers. Thus, scenario 1 identifies the loss level as 12.5% to make the NPV equal to zero. Scenario 2 assumes that the policy reaches a loss level of 11% (higher than projected). The scenario considered in the baseline case assumes that a loss level of 10% is achieved under the assumptions described in subsection 7.3. Scenario 3 assumes a higher growth rate of energy demand of 10%. Scenario 4 assumes that the policy achieves an even lower loss of 7% (with a corresponding higher level of investments).[66] All the cases

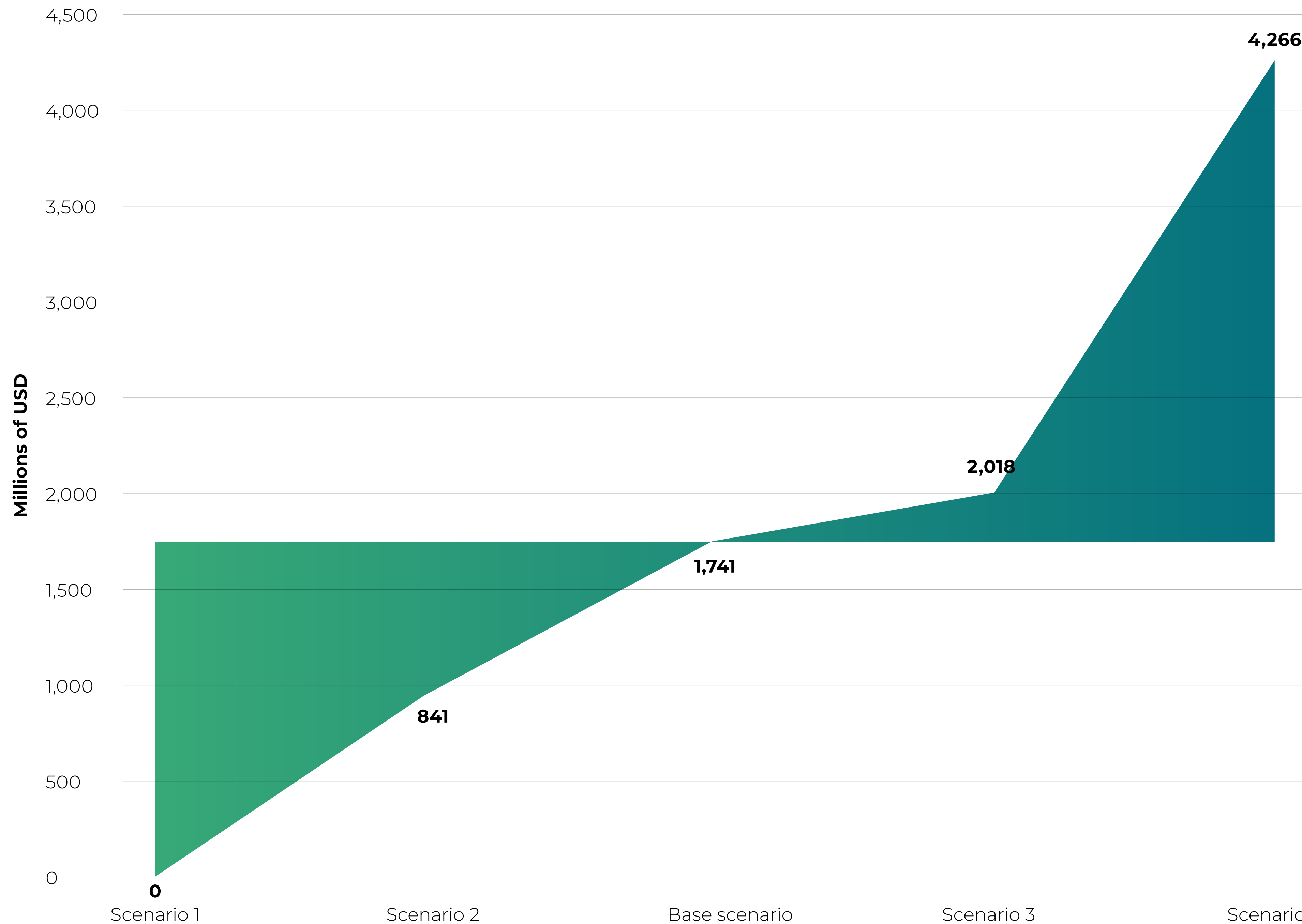
66. The baseline scenario can be considered conservative and greater electrification of the economy is expected, although not yet fully incorporated into the more traditional projection models.

were discounted at a rate of 12%. The benefits would be higher at a lower rate (5%).

Figure 7.3 displays the results. In the baseline case, the benefits reach a net present value of USD 1.7 billion (equivalent to an economic rate of return of 18%). Towards the left, as the policy loses effectiveness (with loss levels reaching more than 11% and 12%), economic profitability contracts, and for loss levels of approximately 12%, the present value of the benefits reaches its inflection point with a value of zero. Towards the right of the baseline case, profits are also higher, with a higher growth rate of electricity demand and/or greater policy effectiveness. While these results are only referential and should be taken with caution, they suggest, consistent with the qualitative analysis in Subsection 7.3, that loss reduction policies may have important benefits but that deviations in expected effectiveness would negatively affect them.

The components of these net benefits are greatly influenced by the financial benefits derived from recovered energy. However, they depend on the ability of the electric utility company to pass on all the costs they incur, including the reimbursement of any resources invested in the rates for the service they provide. Energy savings are also substantial, on the order of 1,900 TWh, which would entail nearly 113,000 kilotons of CO_2 emissions.

Figure 7.3 Net benefits of loss reduction policies



Source: Prepared by the authors.

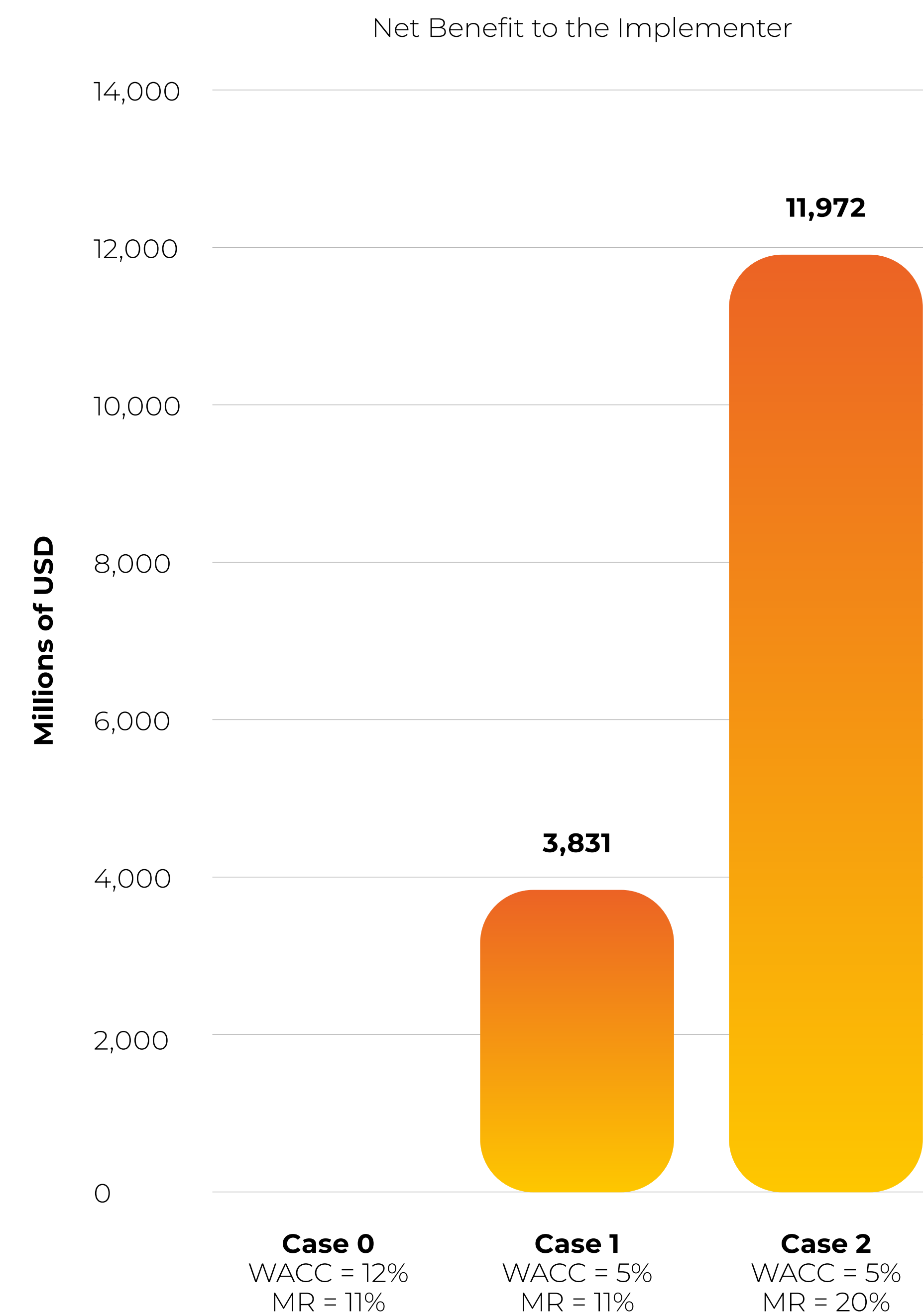
Benefits to the implementer

As previously mentioned, the direct net benefits to the implementer can be particularly significant in contexts where the agent also faces repayment of the investment. In this case, it is necessary to generate financial flows directly that make the intervention viable. The financial flows of implementers have specificities that need to be considered. This analysis outlines a simplified exercise to provide an initial approximation that allows the characterization of some elements influencing these flows. This analysis presents a baseline case considering only incremental net financial income that can be derived from the policy and channeled towards the repayment of the investment. Specifically, it is assumed that the effective profitability margin (PM) on the recovered energy is 11% and 20%, the latter being widely feasible in stable markets with efficient electric companies. This PM can also vary widely among companies (even being negative for operators in difficult markets), and it is possible that the implementation of the policy improves it.

Figure 7.4 summarizes the results of this simulation exercise under different scenarios resulting from the alternative WACC and PM values. One of the most relevant results obtained from this figure is that the financial profitability of the implementer obtained from the policy can be strongly affected by the values of these parameters. Thus, a PM of 11% and a discount rate (e.g., the WACC) of 12% lead to a present value level of net benefits of zero. On the other hand, the benefits for the implementer significantly increase PM and lower the reference discount rate. Under a discount rate of 5% and a PM of 20%, the net benefits would reach approximately USD 12 billion. These values differ from those shown in Section 7.3, because in this scenario, they correspond largely to the recovery of energy that was not previously charged.

Although few analyses of this type include a portfolio of countries, the estimates presented in this chapter are consistent with recent analyses regarding potentially avoided CO_2 emissions. Specifically, considering that assumptions and sources of information differ, the results of our approach are aligned with the global estimates recorded by Surana and Jordaan (2019) and the IEA (2020). See Appendix 3.

Figure 7.4 Net profit to the implementer of the loss reduction policy



Source: Prepared by the authors.

7.6 Between the lines

The parameters used and their values have a concrete significance for policy implementers. The profit margin levels of electric utility companies communicate their financial sustainability and, to a certain extent, reflect their levels of efficiency and the institutional conditions in which they operate (e.g., the degree of rate distortions and regulatory stability). As shown, these conditions determine the financial profits associated with implementing the policies but will also condition their operational viability in the long term.

Likewise, the WACC reflects the financing costs at which the company can access the resources necessary to deploy the policies. Indeed, the high cost of access to credit can restrict their ability to implement investment programs. Moreover, within the framework of the type of investment analyzed in this study, it is important to have adequate financing terms that adjust to the expected flow of repayments derived from their implementation. Both financing costs and adequate terms may be lacking for companies facing acute problems of electrical/financial losses.

However, a central underlying assumption is that policies will effectively achieve user regularization objectives within the planned times. As discussed in previous chapters, various factors can challenge this key assumption, including, for example, the compatibility of incentives (in the markets) for executing the policy to economic and/or political crises that affect both the ability to execute the investments and their viability in more unstable political and social environments.

In summary, the results presented above are difficult to achieve in practice. Persistent failures in the operation of electric power systems have made it difficult to reduce electricity losses to efficient levels. For example, the underlying elements that may explain the persistence of this problem and the low effectiveness in solving it would include the consistency of policies over several electoral periods, which has always been challenging. On the other hand, in recent years, the region's countries have been confronted with difficult macroeconomic and political scenarios, and the outlook for the coming years is cautious. Therefore, multilateral entities can be more active in designing, implementing, and maintaining these policies. Technical and financial support are equally relevant for effectively achieving and controlling loss reduction goals.

The political, economic, and social dynamics of each country represent significant obstacles in strategies aimed at loss reduction.

Box 7.3
Optimum electrical loss levels

Optimal or efficient levels of electricity loss depend on the context and may vary between companies (in the service area) and countries. As a result, they are not easy to estimate, given that they are subject to the specificities of the territory and socioeconomic conditions of the service areas of electric utility companies. For reference, in a recent study, the IEA (2020) used 5% as an efficient loss in transmission and distribution. Other estimates indicate that technical losses exceed 9% in inefficient systems and below 6% in efficient systems (Smith, 2004; Antmann, 2009).

These efficiency levels affect calculating the costs and benefits of reducing electricity losses. For example, setting a policy goal of electrical loss levels of 5% would increase investment needs by 60% and practically double the net benefit compared with the above estimations. In other words, achieving lower loss levels translates into higher levels of efficiency, which would increase energy savings, reduce polluting gas emissions, and produce greater returns for electric utility companies.

Consequently, the estimates presented here can be deemed conservative. However, it is important to note that the costs incurred to achieve lower loss levels may be greater. Generally, loss reduction programs suggest that if one starts from a high level of losses, initial investments in the program produce greater recovery. From the perspective of electric utility companies, this means that loss reduction programs can have diminishing returns, achieving efficient levels that are generally costlier.

Although international experience suggests that efficient loss levels in the long term lie below the assumptions adopted in this exercise, the cost-benefit balance may differ significantly at the level of the electric utility company. Electric utility companies mainly serving urban areas can define relatively low-efficiency loss levels, around 5%. However, companies serving areas where the population is dispersed and/or exhibits greater socioeconomic complexity could incur higher efficient losses.

Although there are differences between countries, and even within each country, the results presented here and the experiences discussed in Chapter 5 suggest that the levels of electricity losses lead to economic losses for a country and region. Therefore, addressing this problem would produce net benefits for society and the electricity sector. The challenges inherent in this issue, arising from its related social and policy connotations, are discussed in Chapter 8.

7.7 Conclusions

In light of the scenario of electrical losses in the region, the factors influencing them, and the measures considered for their reduction, this chapter undertakes an analytical exercise to assess the net economic benefit of implementing a policy to reduce these losses. Both consumers and electric companies would benefit from efforts to reduce losses to prudent levels, as this would decrease the pressure on electricity tariff costs, reduce financial losses, and diminish greenhouse gas emissions.

The economic costs and benefits associated with a target level of loss of approximately 10% in Latin America and the Caribbean are estimated through a simulation exercise. In the absence of such a policy, it is estimated that approximately 8,000 TWh will be lost in the next two decades, of which 3,300 TWh represents losses of more than 10%. Therefore, the cost of permissiveness in the current situation is significant. Annual losses of more than 10% are, on average, equivalent to approximately all wind and solar power generation available in 2021. In cumulative terms, these 3,200 TWh are equivalent to five times the net electricity generation of Latin America in 2019, and the monetary value is higher than Colombia's GDP in 2018. Given that these levels of losses are considered economically feasible to eliminate, the implementation of loss-reduction policies represents a necessity rather than an alternative.

In a scenario with a loss reduction policy, the investment required for countries to converge to levels no greater than 10% is estimated to be close to USD 8.5 billion by 2021. This policy would recover more than 1,900 TWh owing to the gradual nature of its implementation and the achievement of established goals. Such a policy would achieve a positive net economic benefit on the order of USD 1.7 billion (in 2021 dollars) and energy savings that, in the absence of the policy, would have generated 113,000 kilotons of CO2 emissions.

In this regard, not deploying a regional policy to reduce losses can be an obstacle to climate-change mitigation efforts and the financial sustainability of companies. This is even more urgent in countries with high levels of losses, where the economic benefits of implementing policies are greater in financial, social, and environmental terms.

However, the degree to which the advantages of these policies prove effective relies on a range of both internal and external elements to a moderate extent. Specifically, the capacity of an electrical utility corporation to secure financing under conditions that align with the nature of the prospective investment and to function within an institutional framework that is both fiscally sound and foreseeable.

Based on observations from recent decades, the most challenging aspect of achieving positive net benefits is the effectiveness of implementing these policies. The deployment of physical infrastructure is not technically or financially simple, but experience and knowledge show that it can be performed successfully. Multilateral banking can facilitate or structure financing schemes that adapt to the implementation profile of the investment and reduce its weight and the opportunity cost of its availability. Perhaps the most challenging aspect is institutional frameworks, regulatory consistency, and political support, as they can be relevant or more to achieve loss reduction and control goals. Moreover, underlying social and political factors can add substantial complexity, some of which are discussed in the remaining chapters. The estimates provided in this chapter suggest that, despite the cost and complexities that need to be addressed, reducing current levels of electricity losses would lead to potential benefits to society and the environment.

Chapter 8

Is there a social demand for irregular connections?

The persistence of high electricity losses shows that there are dimensions that are adverse to the electricity market operation that have not been overcome. In particular, part of the complexity of the problem is associated with the fact that a substantial proportion of electricity losses originate at the distribution level, presumably originating from energy theft and concentrated in lower-income areas. An underlying aspect of this situation is that public services are involved in the context of political sensitivity. For example, evidence suggests a positive correlation between electricity loss levels and political interference in the sector (see, for example, McRae, 2015; Kojima, Bacon, and Trimble, 2014). Such interference is motivated mainly by the expectation of obtaining political support under the assumption that free services, although of poor quality, are acceptable to the population (Di Bella et al., 2015). Incorporating factors associated with user preferences constitutes one of the greatest challenges faced by those in charge of interventions to reduce or control losses. This challenge also coincides with another widely known challenge in providing public services: finding a balance between providing affordable access to quality electrical services and guaranteeing the financial sustainability of companies in the electric power system.

It is, therefore, crucial to understand how user preferences condition the interactions between various actors, which can partially explain the perpetuation of the problem of losses. For example, the distribution preferences of users, their perception of infrastructure services, and their preferences regarding service quality can influence how political interference in the electricity sector and irregular power consumption are perceived.

To balance the dimensions described, this chapter provides a vision of the demand side that leads to finding balances that benefit all the market actors. To achieve this objective, we discuss the economic policy factors that could explain the persistence of losses. We then explore the general opinions of the population regarding the state's role in providing public services. Subsequently, we discuss some evidence of user preferences and attitudes about electricity services within the framework of loss-reduction programs. Specifically, this chapter seeks to answer the following questions: What are users' perceptions regarding the government's role in providing public infrastructure services? To what extent are they willing to pay for improvements in the electrical services? What are the most relevant service improvements for the users? What would their level of satisfaction be if they went from informal access to formal access? This is expected to provide information to the people responsible for formulating policies regarding the perceptions of electric utility users and their preferences in contexts characterized by high theft of electricity and/or informal connections with low-quality services.

8.1 Tolerance of energy losses

The fundamental role played by infrastructure services in ensuring an adequate quality of life is widely accepted and not subject to debate. Therefore, it is surprising that a prolonged situation prevails in which these services present precarious levels of quality that harm lower-income families, smaller businesses, and other actors in the market. For example, a common situation is one in which the quality of these services suffers because they are heavily subsidized or even provided free of charge. This situation coincides with the financial difficulties faced by infrastructure companies.[67] It is then a trap characterized by low quality and high subsidies in the infrastructure sector.[68]

An explanation for how this occurs in political economy literature has to do with the possibility of obtaining political returns from this type of balance. In situations of marked income disparities, deficiencies in the provision of social programs, and high rates of informality, which include disorderly growth without adequate infrastructure in cities, it is observed that free access to infrastructure services, even if of low quality, may be accepted by vulnerable households. In such circumstances, there may be political incentives to expand irregular and low-quality basic infrastructure such as power grids. Evidence shows that energy losses follow economic and electoral cycles (Golden and Min, 2012, for local governments in India). Furthermore, it can be argued that low levels of enforcement and compliance in developing countries emerge from politically motivated decisions rather than problems with state capacity (Brollo et al., 2014; Casaburi and Troiano, 2015; Ceni, 2014; Loayza and Rigolini, 2011; Feierherd, 2022; Holland, 2015).[69] In short, political decision-makers can interpret the signaling of the population's demand for counter-cyclical measures in favor of expanding informal social transfers, such as irregular access to electricity services.

On the other hand, Latin American readers will not be surprised to hear that the provision of infrastructure may be subject to clientelism. During election campaigns, promises are often made to the most vulnerable groups to expand and guarantee subsidized access to basic services, such as electricity, water, and sanitation. The problem is that when these promises are not accompanied by infrastructure plans that guarantee the quality of the services and the financial sustainability of

67. In the case of electricity, previous chapters have documented how energy losses can in turn mean significant financial losses for electric utility companies.
68. For example, Mc Rae (2015) used these terms to refer to the case of the electricity sector in Colombia.
69. Indeed, there is evidence that either the level of tolerance regarding violations of the law or the degree of compliance with the norms may depend on political factors, although in sectors other than those discussed in this book. For example, political explanations of state flexibility have been related to issues such as the behavior of ideologically based parties that represent formal and informal workers (Feierherd, 2022); with the effects of international trade on labor informality (Ronconi, 2012); with the implementation of social policy and non-compliance with conditions (Díaz Cayeros, Estévez and Magaloni, 2016; Brollo, Jauffman and Ferrara, 2014); and with the class conflict around street vending and unlawful occupancy (Holland, 2015).

the companies that provide them, situations arise that can even harm end users.[70]

In fact, we have already seen how the balance between low quality of service and high losses can be prolonged over time. Today, it could be interpreted as the result of "social norms" that govern the perception of infrastructure services. In the case of the electricity sector, Burgess et al. (2020) refer specifically to the case of the social norm of treating electricity as a right and explain how such a norm can undermine the goal of universal access to reliable electricity:

1. Because electricity is considered a right, subsidies, theft, and non-payment are widely tolerated, while rates that do not cover costs, unpaid bills, and illegal connections to the grid become an issue accepted by the system.

2. Electric utility companies lose money for each unit of electricity sold and lose large sums in total.

3. Distribution companies have no choice but to ration supply by limiting access and service hours.

4. Market forces no longer govern energy supply, as the link between payment and supply has been broken; those who evade payment tend to receive the same quality of supply as those who pay in full.

Explanations related to political interference in the electricity sector and the perception of electricity as a right can be considered complementary. It is apparent that, in contexts of institutional weakness and economic-social stress, they would lead to counterproductive results for society. The question that arises is how persistent tolerance can be for this type of precarious balance because it can be characterized as an inefficiency trap that primarily harms the most vulnerable people. These inefficiency traps tend to be caused by the absence of progressive social policies to serve vulnerable sectors. In other words, it is more likely that losses in the form of informal transfers are permitted or tolerated in the context of institutional disarticulation for the effective delivery of basic services and social protection instruments. In turn, this format of informal transfers is more likely in environments with weak institutions.

However, the fact that losses are typically associated with low levels of quality contrasts with the fact that the population is currently demanding significant improvements in various areas, not only in infrastructure access but also in quality. These demands reflect the levels of development that a region is going through, where citizens' income has been gradually increasing, and new technologies are being integrated into the economy. Hence, there is an expectation that the basic infrastructure will no longer restrict growth opportunities. That is, social demands need to be well understood and transparent to establish guidelines for improving the population's well-being.

70. Figure 4.7 shows the relationship between low energy losses and electric service quality. However, the effects on the well-being of users can be even greater. For example, Jiménez Mori et al. (2016) document how families perceive high risks associated with the low quality of public services, specifically the instability of electrical voltage and the low quality of supplied water.

The willingness to pay (WTP) offers insight into the value that consumers and businesses place on reliable electricity supply. Various studies indicate that households are willing to pay additional amounts to ensure uninterrupted electrical service.

What are the priorities of the end users?

This section explores how end users prioritize the provision of public services in relation to other areas, such as access to education, health, or housing. This detailed view of users' relative importance to accessing public services provides insight and a starting point for adopting reforms based on such preferences.

Figure 8.1 shows the areas in which the population considers that government aid should be concentrated according to the income range of respondents. This figure draws on information collected in 18 Latin American countries between the third quarter of 2020 and May 2021, with users expressing their opinions in six areas:

1. Employment.
2. Access to education and health.
3. Housing and food.
4. Public services (energy, water, and sanitation).
5. Monetary aid.
6. Internet access.

As can be seen in the figure, regardless of income range, support for finding and/or maintaining employment constitutes the highest priority expressed by respondents. This is followed, by a wide margin, by access to education and health, housing, and food.

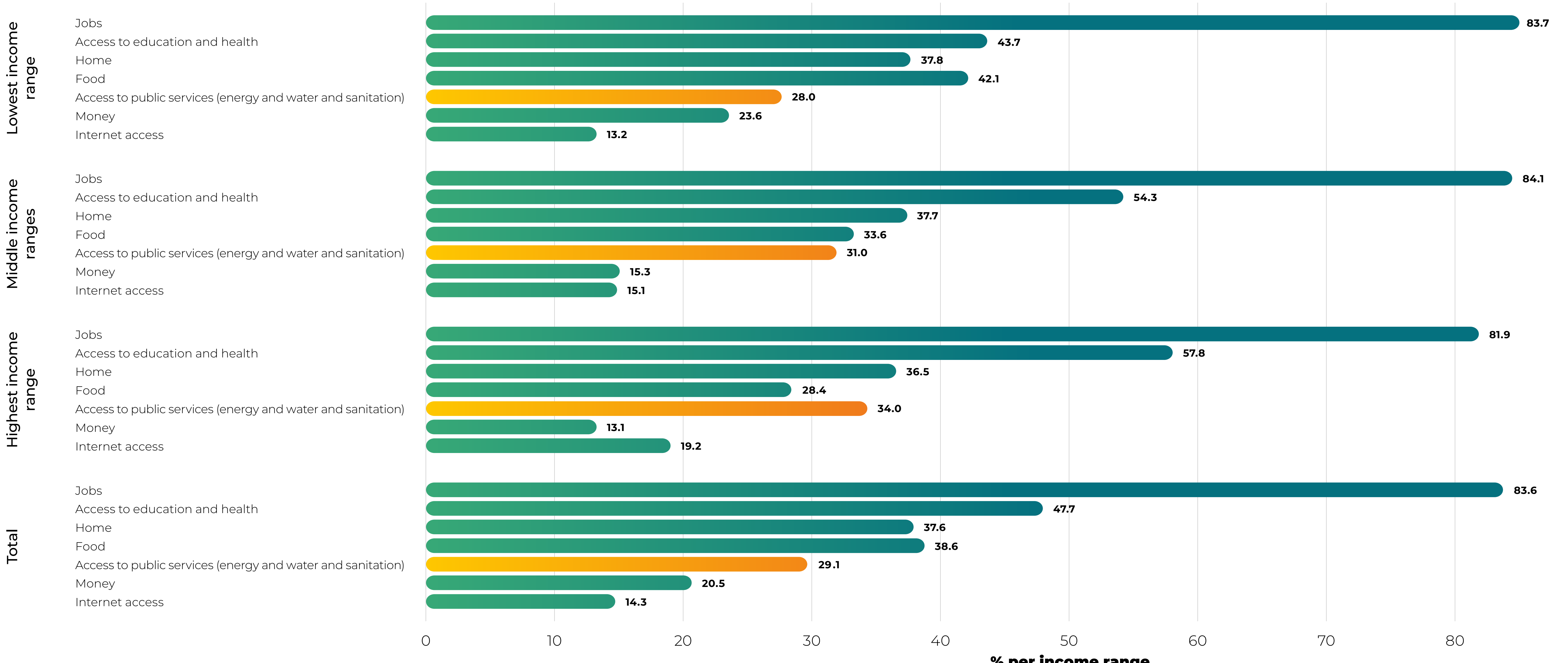
On the other hand, access to social infrastructure and essential infrastructure services (such as water, sanitation, and electricity) is considered a higher priority than monetary aid and Internet access across all income ranges. These results are not entirely unexpected. Direct transfers or government support via cash handouts are transitory in nature and have limited scope in terms of population coverage. In contrast, physical and social infrastructure (such as schools and access to energy) are difficult to exclude and can be considered permanent assets.

One remarkable result is that Internet access is among the services considered less indicated to receive government support. Indeed, one factor that can explain this result is the fact that most telecommunications services are provided by the private sector, which changes their perception regarding services, such as education or electricity, where the state has been most active. This pattern of user attitudes towards different infrastructure services, electricity versus the Internet, also appears in low-income regions, but with a similar market structure.

In general, it can be said that the results discussed are consistent with the period in which the survey was carried out, as well as with the nature of the services analyzed. The preference for support for maintaining employment can be associated with the fact that the survey was conducted during the COVID-19 pandemic. However, the use of services such as the Internet depends on the existence of essential infrastructure (such as energy and transportation).

71. For example, according to data reported by Burgess *et al.* (2020) from the household survey conducted between March and August 2017 on the "Bihar Electrification Project", the vast majority of users in Bihar, India, do not expect to be penalized for paying a bill late (76.3%), for illegally connecting to the grid (73.9%), for wiring a meter (78.0%) or even for bribing electricity company officials to avoid payment (63.3%). These attitudes contrast markedly with the way in which these same users perceive payment for private goods such as cell phones, for which they do not exhibit social demands as in the previous case. The authors show that respondents spend three times more on mobile phones than on electricity (1.7% versus 0.6% of total spending). This small share in electricity expenditure suggests that non-payment is not due to the inability to pay for the service, but rather to a social norm.

Figure 8.1 How do you think the government should help the poorest, by giving them...? (% per income range)



Source: Prepared by the authors based on Latinobarómetro (2020).

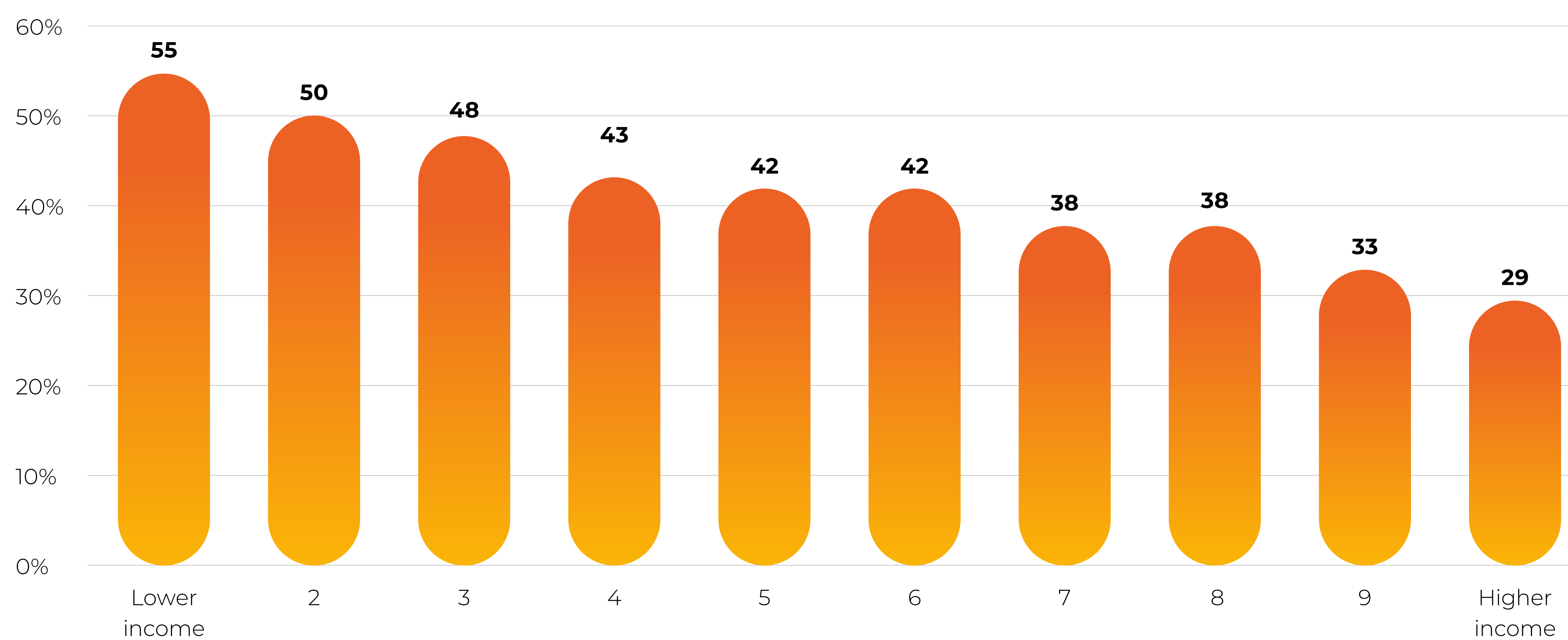
Nota: The Latinobarómetro survey defines 10 income ranges for each of the countries in which the respondents reside. In the figure, they appear grouped into three ranges: lowest income (1–3), middle income (4–6) and highest income (7–10). The figure reports the percentage of respondents who mentioned any of the areas. Each user could mention more than one priority area of government support for the poorest. The total number of respondents excludes those who did not identify the income range to which they belong and who did not mention any priority. The estimations are weighted by the expansion factor. The survey was carried out between the third quarter of 2020 and May 2021 in 18 Latin American countries.

The results described in Figure 8.1 arise from the population's perception of the role played by the State in terms of social support in different areas. Although they show that there is a social demand for support provided by the government in the area of infrastructure, they also seem to indicate that there are demands that are considered of greater priority/urgency by the population. What's more, this ranking of priorities seems to be independent from the income level of the respondents. These response patterns by the population contrast with one of the most common arguments used to justify the delivery of subsidies, as well as interference with the electricity sector: that they have a social nature and have a high impact on the most vulnerable groups.

At the same time, it should be noted that the demand for State assistance through infrastructure services does not necessarily imply an indiscriminate social demand for free infrastructure services. For example, Figure 8.2 shows the percentage of households that are in favor of the State providing the aforementioned goods and services free of charge to the poorest (versus through subsidies/partial contributions). Even lower-income households (approximately 45%) do not appear in favor of free access to State goods and services. This percentage decreases to 30% among respondents in the higher income segments.

In summary, the descriptive evidence suggests that, while there is a social demand for government involvement in providing infrastructure services, the population tends to prioritize other areas of intervention, such as employment opportunities, access to education and health, and food security. Furthermore, there is no consensus on the issue of free provision of services by the State. Even among the lowest-income groups (deciles 1 to 3), 50% of respondents believed that these services should be free, while the other 50% stated that they should be paid for..

Figure 8.2 Percentage of households that are in favor of free access to State goods and services



Source: Prepared by the authors based on the Latinobarómetro Survey (2020).
Note: The Latinobarómetro survey defines 10 income ranges for each country in which they classify their respondents. The estimates are weighted by the expansion factor. The survey was carried out between the third quarter of 2020 and May 2021 in 18 Latin American countries.

8.2 User preferences

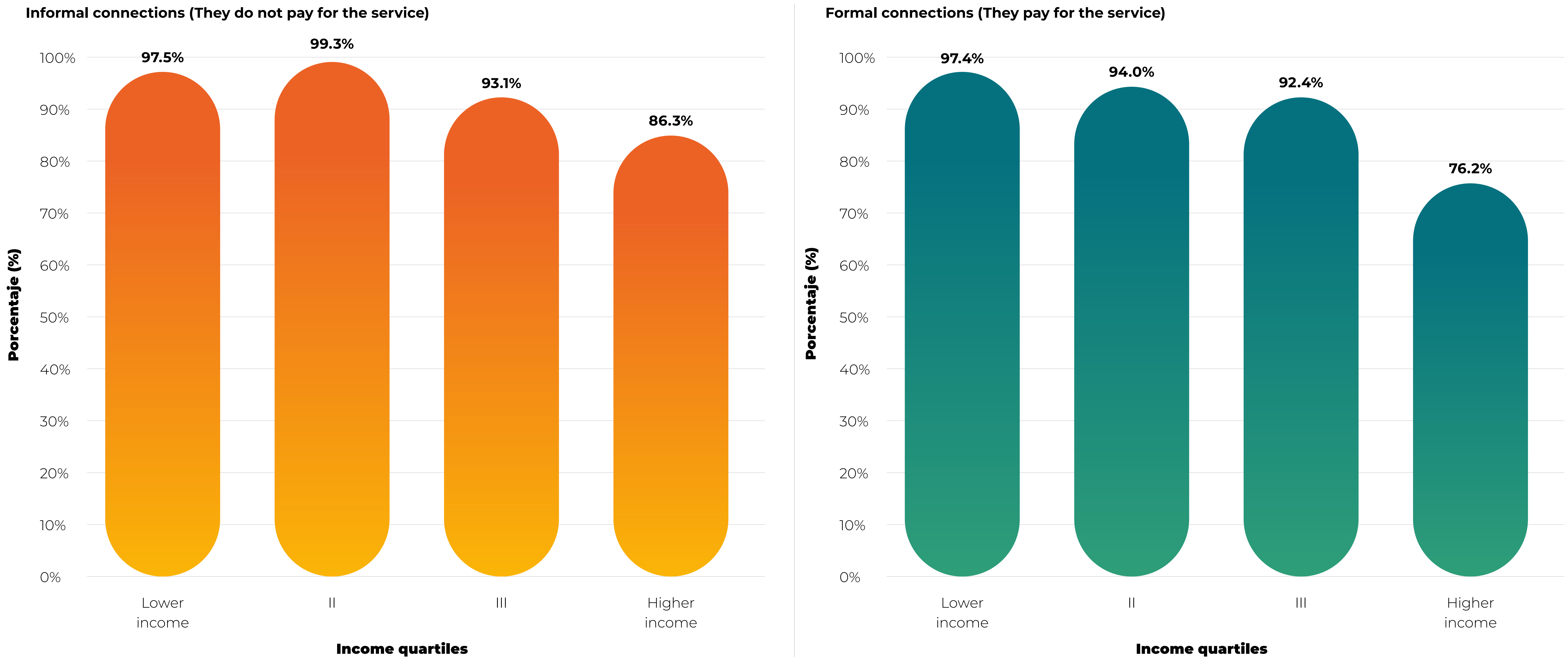
Value conferred by users on the provision of better electrical services

This section focuses on the willingness to pay to become customers, thereby reducing non-technical electrical losses. A key aspect of the ongoing issue of losses is whether households are willing to pay for the services. Empirical and anecdotal evidence indicates that households attribute significant value to electrical services and are willing to transition from informal connections to paying for these services in exchange for improvements in supply and reliability. This valuation reflects the essential nature of electrical infrastructure services in families' and businesses' daily lives. Specifically, specialized literature on Latin America and the Caribbean (LAC), as well as other regions, suggests that users value the continuity and availability of the service, as well as its quality, in terms of voltage stability (Jiménez Mori et al., 2018; Jiménez Mori et al., 2016; Abdullah and Mariel, 2010; Hensher et al., 2015).

For example, in the Dominican Republic, Jimenez-Mori (2018) suggested that the vast majority of households experiencing some form of rationing or whose electrical service is of low quality would be willing to pay for its improvement. This result is consistent among the consumer groups of electric companies, that is, both informal users and those registered with a meter, as both groups are affected by some quality deficiency. Figure 8.3 shows that both groups, informal users and formal clients, between 97% and 76%, have positive valuations for possible improvements in electrical services. This implies that regardless of their income level, a user or client, at least three-quarters of households would be willing to pay more for service regularizations, which implies an improvement in the service.

Figure 8.3 also suggests that the greater the improvement, the larger the group of users willing to formalize their situation. In the highest income quartile, only 76% of clients would be willing to make additional payments if the quality of the service improved, compared to 86% of informal users. In this aspect, the difference between formal and informal clients can be attributed to the fact that the former tend to receive better quality services for which they pay and do not see a need for improvement in the quality of services..

Figure 8.3 Would users be willing to pay more for better services?



Source: Prepared by the authors based on data from Jiménez Mori (2018).

Nota: Willingness to pay is derived from positive propensities to pay for service improvements. These propensities were estimated based on decision experiments designed for informal and formal consumers.

Relevance of electric service attributes

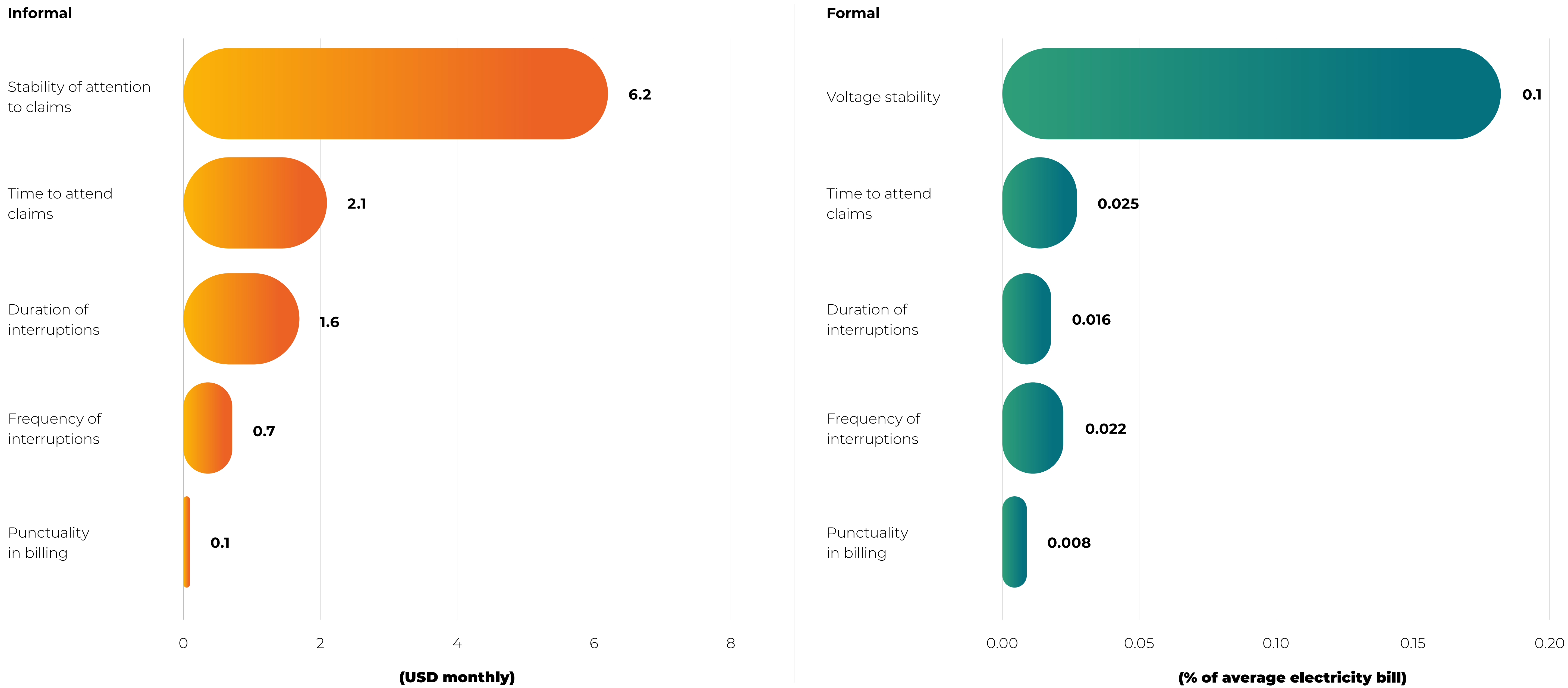
From the above, it follows that when considering measures to improve electric services, it is necessary to clarify user preferences. The literature indicates that the latter can distinguish the attributes that define electric services and establish an order of preferences in this regard. Although this order could vary depending on the context, the characteristics of the electric service, and factors such as the climate and the users' habits, among others, there is a certain degree of consensus on the main attributes and their relative importance, particularly in developing countries. For example, Appendix 4 presents a series of studies conducted in developing and developed countries that identify several attributes of electric utility services.

For LAC, the cases of the Dominican Republic and Paraguay illustrate the existence of marked preferences and valuations regarding attributes directly related to energy supply: voltage stability and frequency and duration of interruptions. Commercial attributes are also mentioned by formal and informal customers, although hypothetically, by the latter.

Figure 8.4 shows that after the attributes are directly related to energy supply, the commercial attributes mentioned by customers and users are response times to complaints and punctuality in the delivery of bills. Qualitative evidence suggests that these two attributes affect consumer trust in utility companies. Specifically, punctuality in the delivery of consumption-based bills is appreciated by companies as an act of transparency (Mori et al., 2016). Likewise, the response time to complaints could be interpreted as a signal of the degree of sensitivity of consumers to company performance when unforeseen short-term events occur (such as service failures caused by weather events). These aspects may be relevant for systems facing reforms and the need to build and/or consolidate political and population support.

Taken together, the ratings awarded by users to improvements in electric utility services and their ability to distinguish between their various constituent attributes indicate ample space to take advantage of these preferences through standardization programs that reduce electricity losses and increase the quality of services. In the next section, we discuss the effects of such programs on end-user satisfaction.

Figure 8.4 Order of importance of the attributes of electric utility services



Source: Prepared by the authors based on data from Jiménez Mori (2018).

Note: Willingness to pay is derived from positive propensities to pay for service improvements. These propensities were raised based on decision experiments specifically designed for informal and formal consumers.

User satisfaction

From the public policy perspective, it is worth asking whether the net result of increasing the quality of the service and charging it translates into net benefits for the user.[72] Evidence indicates that service improvements translate into social welfare gains via the convenience of improved services. Gains derived from utilization for productive uses have also been documented, reflected in improvements in user productivity and income, as seen in Box 7.1 in the previous chapter. Another angle from which to evaluate the social gains of reforms that reduce commercial losses and improve the quality of public services involves observing the satisfaction levels of users who have experienced them.

Although the relationship between service quality at higher costs and customer satisfaction continues to be an area where the evidence is relatively new and limited, studies suggest that the net effect is increased satisfaction with the services provided. Specifically, and consistent with the preference ranking recorded in Figure 8.4, user satisfaction is strongly influenced by service quality attributes, such as reliability (number of interruptions over a given period), voltage stability, and response to complaints.

Furthermore, empirical evidence indicates that although service costs are strongly related to satisfaction, users can differentiate between the service cost and costs related to the quality of supply and/or commercial costs. Indeed, consumers' perceptions of price fairness seem to be associated mainly with attributes related to the cost of the service (average price of electricity, subsidies, and rate schedule), and are cognitively separated from those regarding attributes related to service quality. This aspect is also relevant to introducing reforms that lead to systematically reducing energy theft because the acceptability of reforms in the sector can be promoted to the extent that the well-being of users responds to the improvement in the different attributes of the electric service.

For example, for Ecuador and the Dominican Republic, evidence suggests that loss reduction programs through the normalization of connections that improve the quality of services, in turn, lead to improvements in household well-being and satisfaction. In the case of Ecuador, it was found that after the normalization of electrical connections, households increased their electricity consumption by around 100%, suggesting that the previous condition restricted their needs and, therefore, reduced their well-being. In the case of the Dominican Republic, evidence indicates that the positive marginal effect on user satisfaction resulting from improvements in service quality is greater than the combined negative marginal effect of price increases. Furthermore, in this case study, the estimates show no evidence of attitude adaptation, suggesting that service improvements are associated with lasting increases in consumer satisfaction.[73]

72. Although the quality of the services offered must meet regulatory standards, in practice there may be substantial discrepancies between said standards and the quality of the service actually provided.
73. See Jiménez Mori (2019, 2021) for the cases of Ecuador and the Dominican Republic, respectively.

Significant and consistent improvements

A relevant aspect that emerges from empirical evidence is that the improvements that users demand—for which they are willing to pay and with which their well-being increases—need to be substantial to be internalized. On the other hand, marginal improvements can only be translated into equally marginal propensities to pay and temporary increases in satisfaction levels. This pattern indicates that user standardization policies or measures must ensure high levels of quality of the electric service and its long-term permanence to be effective. This regularity seems to be present in both empirical and qualitative evidence. It is consistent with the judgment that a public service that is not reliable is of little value to end consumers.

Figure 8.5, for example, shows the electric service profiles that characterize the different probabilities of acceptance of standardization programs based on a field study in the Dominican Republic (Jimenez Mori, 2018). Although it is clear that the additional cost negatively affects acceptance of the change, improvements in other attributes tend to compensate for it, thus increasing the probability that users will accept the reform and become customers. As previously noted, the attributes that have an important weight in the probability of users accepting reforms are voltage stability and continuity of service. In particular, at the highest acceptance levels (where the probability of acceptance of the reform is approximately 77%), households declare that they are willing to accept two additional hours of interruptions per month in exchange for greater voltage stability.

Another relevant element in designing effective interventions has to do with rate levels or the cost already paid by customers of the service, particularly when these are the beneficiaries of the reforms. Specifically, users who are already paying for electricity services at a relatively high cost constitute a segment that requires particular attention during implementation. For example, it may be relevant to make a distinction about the reasons why these users would be affected by the reforms, which may be because they were not previously complying with their obligations as users or because the reform may mean a rate adjustment for redistributive purposes. Consequently, the first step is for electric utility companies to identify and characterize their user base in sufficient detail.

74. Also, refer to Deutschmann *et al.*, (2021).

Figure 8.5 Probability of accepting service normalization

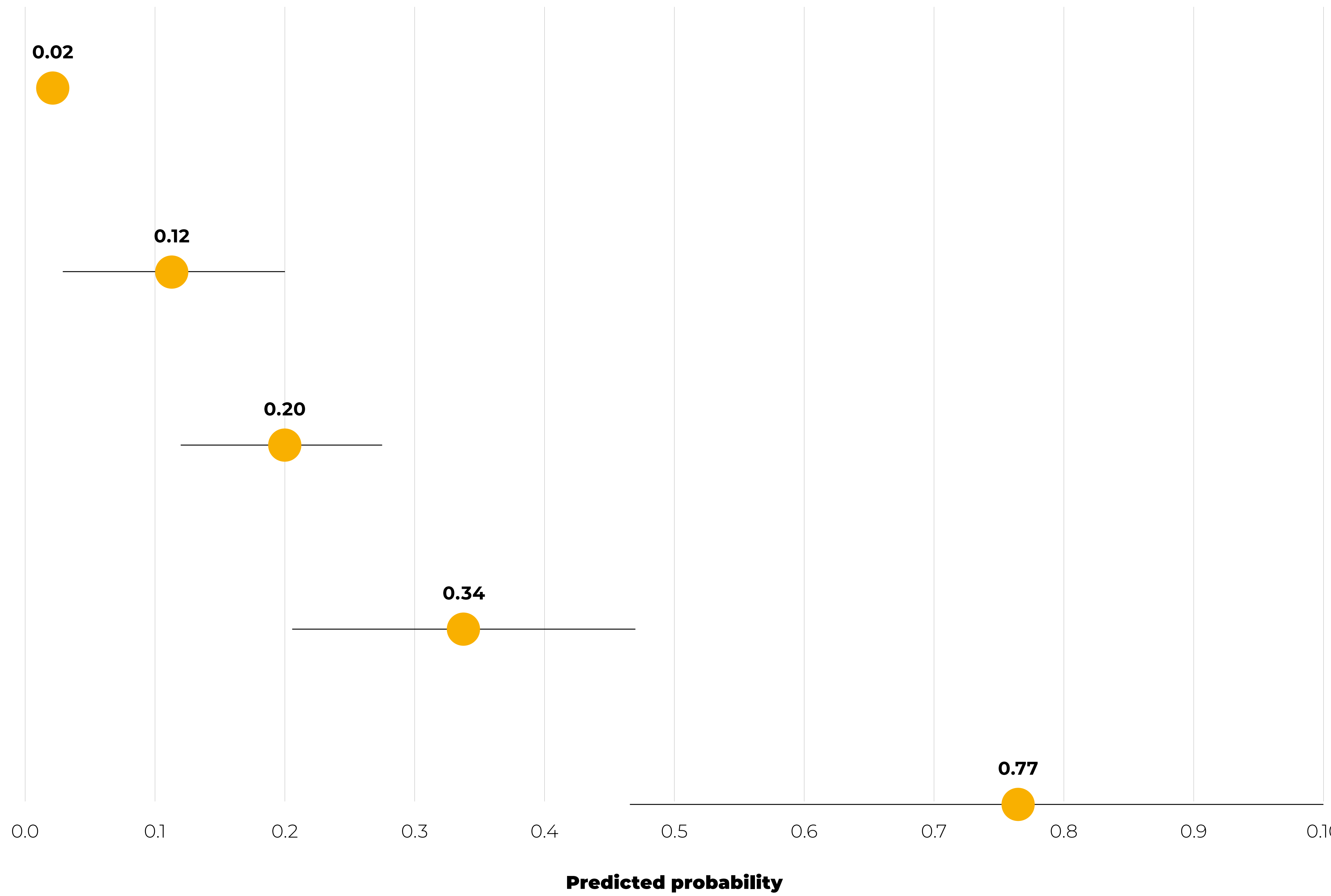
P1 Frequency of blackouts: one per week; 0.2; Voltage: Instability occasionally; Length of blackouts: 8 hours; Puntuality in delivery of bills: Punctual; Timing of the blackouts: Night; Response time to claims: Delays in reponse

P25 Frequency of blackouts: Once every two months; 0.5; Voltage: Very stable; Length of blackouts: 1 hour or less; Puntuality in delivery of bills: Always delays; Timing of the blackouts: madrugada; Response time to claims: Delays in reponse

P50 Frequency of blackouts: one every two weeks; 0.35; Voltage: Very stable; Length of blackouts: 1 hour or less; Puntuality in delivery of bills: Always delays; Timing of the blackouts: madrugada; Response time to claims: Delays in reponse

P75 Frequency of blackouts: one per week; 0.15; Voltage: Instability occasionally; Length of blackouts: 8 hours; Puntuality in delivery of bills: Always delays; Timing of the blackouts: Afternoon; Response time to claims: Quick response

P99 Frequency of blackouts: One per month; 0.15; Voltage: Very stable; Length of blackouts: 10 hours; Puntuality in delivery of bills: Always delays; Timing of the blackouts: madrugada; Response time to claims: Delays in reponse



Source: Prepared by the authors based on data from Jiménez Mori (2018).

Note: Estimated probability for the combination of attribute levels corresponding to the 1st, 25th, 50th, 75th, and 99th percentiles of the predicted probability distribution.

8.3 Affordability

As indicated at the beginning of this chapter, loss reduction measures and measures taken in the energy sector, in general, can be influenced by criteria that prioritize price aspects, sometimes with populist objectives. For this type of reform, these influences generally focus on the relevance of the cost of the service to the detriment of other attributes of public services, such as reliability and continuity. In this regard, there seems to be a bias towards cost over quality of services. This bias has had counterproductive effects on supply sustainability and appears to have ignored the voice of end consumers.

On the other hand, it is necessary to emphasize that even when users value the quality of the electric service, its price still constitutes a central element for the acceptance of the reforms. Moreover, ensuring the affordability of electric services for vulnerable groups constitutes one of the central objectives of public policy, which is why the effects of the reforms must be carefully evaluated in terms of their effects on equity. We should also consider that consumer preferences and assessments of improvements in service quality may vary significantly, both within the same segment and between its different types (homes or businesses, for example). However, it is essential not to lose sight of the fact that even if the predisposition to pay appears remarkably heterogeneous, it tends to be positive. In other words, there is a demand for improvement in public services and an associated willingness to pay.

Therefore, to separate responsibilities that facilitate the management of the sustainability needs of the electric power system and its equity elements, it is recommended to address affordability problems separately from those of electricity losses. This is because tolerance towards electricity theft and the rationing of electrical services have been shown to constitute inadequate measures to address the underlying social problem. On the contrary, they can generate severe losses in the well-being of society, restricting their energy consumption capacity and/or generating inconveniences owing to the low quality of service.

For the reforms to improve equity and be politically viable, it will be necessary to discern between the appropriate and most effective mechanisms to ensure that they benefit all users, particularly the most vulnerable. For example, subsidized rates and, more generally, monetary transfer programs can directly serve lower-income groups, minimizing distortions in market operations. Thus, they can be helpful in designing strategies that consider diversity in valuations based on the social and economic characteristics of the target population. This can contribute to implementing appropriately targeted social programs that reduce the possible adverse distributional effects. Achieving affordable prices for electrical services requires comprehensive efficiency in the electrical sector, wherein loss levels must be reduced. In a complementary manner, energy transition policies in the generation subsector can also contribute to this objective by introducing cleaner and more cost-efficient generation capacity.

8.4 Conclusions

This chapter discusses how there can be a certain tolerance of energy losses for political and economic reasons and how this tolerance contrasts with the incentives and preferences of users who increasingly demand a better quality of service. Contexts of institutional weakness, with disarticulation and/or absence of progressive social programs, tend to cause inefficiency traps that help explain the persistence of electricity losses. The increasing social demand for quality services presents a challenge to this scenario. A central message that arises from this is that achieving affordability of quality electric services, their financial viability, and optimizing efficiency levels are mutually reinforcing policy objectives.

Tolerance to electricity losses not only harms companies in the sector but also end consumers and the economy as a whole. Based on the performance of electricity markets in recent decades, it is unlikely that permissiveness towards losses constitutes an adequate instrument to promote equity in access to electricity services. As a subsidy instrument, it represents not only a non-transparent and highly discretionary means but also its persistence, which has prevented the achievement of fundamental goals such as providing quality services and financial and environmental sustainability for electric power systems. In short, permissiveness towards electricity losses is ineffective and highly costly for providing electric services to vulnerable groups.

Part of the persistence of this tolerance can be associated with a trade-off between increasing the quality of electric services and prioritizing affordability. However, most users will likely value the quality of electric service and express their willingness to become formal customers. Although the cost of the service plays a fundamental role in the acceptability of reforms and measures aimed at reducing energy theft, users also weigh the deterioration of the electric power system infrastructure. Thus, the evidence suggests that users could prefer a better quality electric service, which would allow for implementing normalization programs that reduce electricity losses.

It can be argued that the objectives of loss reduction and equity reinforce each other. Loss reduction measures also tend to improve the quality of public services, directly benefiting users and, by establishing adequate control of the latter's consumption, facilitate better targeting of specific social programs to the most vulnerable groups to meet their needs. Of course, service provision must meet minimum quality standards that are tangible to the beneficiaries, as well as having the capacity to charge users for the service (enforcement) so that users have incentives to comply with their payments.

The affordability and energy poverty issues could be addressed most effectively through well-designed programs targeting vulnerable populations. Subsidized rate schemes or other measures of the same nature, although imperfect, have shown better results in promoting the affordability of quality services. This highlights the integral nature of the operation of the electric power system, in which the reduction of the problem of losses and promotion of a cleaner and more cost-efficient generation park represent the main structural measures to achieve adequate energy prices.

Chapter 9

Perception and tolerance of irregular energy consumption[75]

75. This chapter was written by Santiago López Cariboni. University of the Republic, Uruguay. Economy Department.

One aspect of electricity losses that has received less attention has been the role played by social norms and preferences (Never, 2015) and their relationship with the political economy of irregular access to essential services. Recent findings show that people have a progressive preference for state flexibility in the face of irregular energy consumption (Wong et al., 2021; Burgess et al., 2020; López Cariboni, 2017) and that governments can react to these preferences depending on their ideological orientation (López Cariboni, 2019). The above suggests that governments face a more widespread demand for a deliberate decision not to enforce the law when offenders (beneficiaries) are vulnerable individuals with lower incomes. This evidence is consistent with the persistence of energy theft, particularly via informal connections in lower-income groups (see Chapters 3 and 4).

This chapter reviews recent research on social demand for state permissiveness or flexibility in the face of irregular energy consumption. Here, we show that government and distribution company policies must study the behavioral aspects related to the structures of social preferences, which are markedly stable between and within countries. As indicated in the previous chapter, this permissiveness can occur in low-quality and high-energy theft situations.

First, we discuss the political economy literature to explore government incentives to offer informal transfers. We then describe energy losses and their links to deliberate permissiveness policies. Next, we review the results of experimental studies on preferences for enforcement in the face of energy theft in different developing countries and the underlying political and ideological foundations. We conclude by offering a series of conclusions about what this phenomenon entails regarding public policy.

9.1 The politics of informal transfers

In developing countries, such as those in Latin America and the Caribbean, the benefits from the welfare state fail to protect the informal sector. Social security has traditionally been directed at the formal sector of the economy, which had solidified since the mid-twentieth century when these countries implemented industrialization strategies based on endogenous growth (McGuire, 1999; Huber et al., 2006; Wibbels and Ahlquist, 2011). A typical characteristic of fiscal policy in the LAC is that it lacks the progressivity observed in European nations (Milanovic, 2000). First, eligibility for social security is linked to formal employment, meaning that the main component of social spending corresponds to social programs of a contributory nature (De Ferranti et al., 2004; Huber et al., 2006; Goñi López and Servén, 2011). In addition, its fiscal cost is partially socialized through general consumption taxes levied on the economy's formal and informal sectors.

Second, in the region, transfers and subsidies provide marginal benefits for people experiencing poverty. Subsidies for energy, transportation, tertiary education, and housing loans are mainly captured by the middle and upper classes, who are more intensive consumers of these services (Bril-Mascarenhas and Post, 2015).[76] Meanwhile, recent social policy innovations, such as non-contributory transfer programs, provide no more than a minimum subsistence income and have a limited impact on poverty reduction (Barrientos and Santivañez, 2009; Barrientos and Lloyd-Sherlock, 2002). This could partly explain the relatively solid support of the subsidiary sectors of these policies, such as the middle and upper classes (Holland, 2018), as well as the successful expansion of low-cost policies with limited benefits for vulnerable populations, such as programs for conditioned and unconditioned transfers (Cecchini and Madariaga, 2011; Brooks, 2015).

The political effect of the "truncated" structure of welfare states in the LAC is that the distributive conflict is attenuated or disappears (Holland, 2018). In countries where the welfare state does not cover the poorest and where the middle and upper classes capture a large part of its benefits, individual income is no longer associated with redistribution preferences, as occurs in more progressive welfare states (Beramendi and Rehm, 2015). This has been perceived as a political limitation in achieving a deeper stage of redistribution in the region (Holland, 2015). For members of the lower class, the scant expectations that the expansion of the welfare state will benefit them are compounded by the high costs incurred in overcoming collective action problems and channeling political demands (Rudra, 2002; Rudra and Haggard, 2005; Segura-Ubiergo and Kaufman, 2001; Wibbels, 2006). Therefore, it can be risky for these individuals to invest in political resources and mobilize through legal mechanisms affecting their market income or disposable income (such as taxes, transfers, services, and regulations). Hence, they have a propensity to find alternative and more immediate mechanisms to satisfy basic needs such as housing and access to services.

76. Add to this that social spending can be markedly unstable. For example, although educational spending is the most progressive budget component (Rudra and Haggard, 2005; Albertus and Menaldo, 2014; Ansell, 2010), it is also the most vulnerable to economic recessions and represents one of the most more procyclical aspects of social policies (Wibbels, 2006).

In developing countries, social security primarily benefits the formal sector, leaving the most vulnerable on the sidelines.

The poorest individuals, especially those in the informal sector, have a coherent material interest in tolerance regarding violating the laws that protect private property, which they are more likely to disregard when satisfying their basic needs. According to Holland (2015), this provides a structure of political demand for informal social transfers (known as forbearance). Informal redistribution mechanisms can be economically affordable substitutes for many legal state actions and provide strong political incentives for governments. Furthermore, the informal benefits provided through state inaction allow politicians to send more credible electoral signals regarding their affinity with lower-income voters. This contrasts with the signals provided by the traditional promises of formal social policy, which do not protect these sectors of the population by their design.

Holland (2016) conceptualizes state flexibility as a phenomenon of informal social policy independent of the low capacity of the state. In other words, its emphasis lies on the decision of politicians not to enforce the law—even when they have the capacity to do so— to provide them with informal transfers. Forteza and Noboa (2019) develop a general model that represents the existing dilemma governments face (under the design of commitment institutions) when the state is limited to providing social insurance. In this case, state capacity equates to the underdevelopment of the welfare state and not to technology to enforce property rights. When a portion of people's income is impossible to insure, a benevolent government would have room to provide informal insurance, that is, ex-post insurance, against a negative economic shock. Such informal endowment occurs when the state allows the erosion of compliance with norms.

In a related article, Holland (2015) argues that the violations generated by progressive transfers, that is, those that allow for abstention from complying with the law and that are focused on lower-income individuals, polarize voters who do not receive these benefits (generally those belonging to the middle and upper classes). Data from a survey conducted in Bogotá (Colombia) show that socioeconomic level negatively correlates with the preference for 'permissiveness' in unlawful occupancy and informal street vending. This finding also coincides with evidence from public opinion surveys in various Latin American countries.

In short, the political response of allowing violation of the rules—irregular access to basic services in the present case— is supported by the structure of social preferences that generate such political incentives. The following section presents evidence of the magnitude of losses in the electricity sector, the characteristics of its social coverage, and its link with political decisions. We now describe the social preferences for state permissiveness regarding the irregular consumption of electricity, with emphasis on LAC countries.

9.2 Dimension and determinants of energy losses as informal transfer programs

As shown in Chapters 3 and 7, electricity losses translate into large financial losses for electric utility companies and the environment. We also show that such levels of losses are highly persistent in LAC countries, which suggests a certain degree of permissiveness towards irregular energy consumption.

At the same time, permissiveness seems to be influenced by elements of economic policy. As mentioned in Chapter 8, Golden and Min (2012) analyze local elections and found that electricity losses share the same cycle as electoral periods and economic fluctuations. Because policymakers are aware of the benefits of allowing irregular access to electricity services, they allow informal transfers to increase by being more permissive with irregular connections or disconnections of services during these periods. A similar dynamic can be seen in the case of Uruguay, where economic cycles are positively associated with the levels of non-technical losses (see Chapter 4 and Box 4.3). This logic of discretion is precisely what is suggested by Forteza and Noboa's (2019) theoretical model. Therefore, this is expected to be the case when politicians have incentives to gain political and electoral support among disadvantaged groups in society, typically in developing democracies.

The evolution of electricity losses documented in previous chapters suggests this is a difficult balance to modify. One might then ask what structure of social preferences underlies this balance. The following section presents evidence for this point.

Electricity losses, in addition to causing financial and environmental damage, are influenced by politico-economic dynamics that favor irregular consumption during electoral cycles.

9.3 Preferences for state permissiveness against irregular energy consumption

Recent research has emphasized that access to electricity is seen as a right (Burgess et al., 2020; Tully, 2006). Free access to energy has positive effects on beneficiary users, which may help explain why some groups tend to see irregular consumption as justifiable. In fact, many scholars have identified that ensuring access to electricity can be seen as a collective good (Alesina, Bakir, and Easterly, 1999; Chhibber and Nooruddin, 2004; Banerjee, Iyer, and Somanathan, 2005; Besley and Ghatak, 2006; Abbott, 2001; Min, 2015). Abbott (2001: 32) states that "the security [of electricity supply] is unrivaled in terms of public good. [...] Security of supply also appears to be non-exclusive in the sense that it is difficult to exclude people from the benefits of reducing such risk." Of course, this only occurs up to a certain point, namely, when electricity theft leads to grid overload and power outages (Lewis, 2015; Jiménez Mori, 2020; Burgess et al., 2020).

However, informal access can also be the subject of distributive struggle (Min, 2015). The distributive model of political demand for informal social transfers (forbearance) developed by Holland (2015)[77] assumes that individuals have selfish preferences for penalty allocation. If members of the middle class have no incentive for irregular electricity consumption, then only the poor benefit from weak law enforcement. Therefore, this model predicts that demand for non-compliance decreases as income increases. In this case, lower-income individuals prefer higher levels of non-compliance than middle- and high-income individuals. Individuals who do not benefit from informal transfers should have neutral or regressive preferences for applying supervision and penalties. In other words, this model implies that there is no progressivity in the middle-class tolerance for energy theft.

Little evidence on the tolerance of energy theft shows that this, in turn, depends on different factors, including the socioeconomic level of the beneficiary and the quality of the service they receive. Wong et al. (2021) study perceptions regarding the theft of electricity in the form of illegal cables in rural and urban households in Uttar Pradesh, India. The authors conducted a conjoint survey experiment using a design similar to that proposed by Hainmueller et al. (2014).

Respondents were asked to compare two hypothetical individuals who commit energy theft but who di-

77. This approach, in line with the model proposed by Meltzer and Richard in 1981, offers an interpretive framework for individual behavior concerning the distribution of resources and sanctions.

ffer in social characteristics, such as income, caste, religion, the quality of service they receive, and the service theft strategy by relatives, strangers, and themselves. The study's main results show that the social acceptability of energy theft is influenced by income context and the quality of the electric supply received by hypothetical informal consumers. Specifically, if offenders are offered better services (more hours of daily power supply), the social acceptability of theft is significantly reduced. On the other hand, as the income of informal users increases, the social acceptability of energy theft also decreases. However, it should be noted that the study was carried out in an area of the world where informal consumption is the rule and where a large part of those interviewed are informal users and, therefore, beneficiaries of such transfers.

The social acceptability of electricity theft is influenced by income contexts and the quality of the electrical supply received by consumers.

Using a different recruitment strategy, in the study by López Cariboni (2017), a similar survey experiment was conducted in four Latin American countries, where the participants were mostly regular energy users. The demand for the application of penalties was analyzed according to the individual characteristics of hypothetical people who consume electricity illegally. This study used convenience samples formed through online advertisements. The research was conducted in four LAC countries with samples of the following sizes: Argentina (835), Chile (610), Colombia (599), and Uruguay (1123).

Citizens may tolerate informal behaviors for different reasons. The individual characteristics of offenders may help determine these preferences. That is if citizens have clear preferences regarding "who" should benefit from state tolerance for illegal behavior, estimates of such preferences would reveal the causes of popular demand for political tolerance for irregular electricity consumption. The study by López Cariboni (2017) considered random profiles of irregular users who could assume the characteristics presented in Table 9.1.

Table 9.1 Profiles of irregular energy users

Dimensions	Attribute values
1 **Sex**	Man
	Woman
2 **Age**	26
	37
	58
3 **Education**	Primary
	Secondary (incomplete)
	Secondary (complete)
4 **Children**	None
	Two children
	Five children
5 **Place of residence**	Regular neighborhood
	Irregular settlement
	Rural area
6 **Monthly income**	0.5 x Poverty line
	1 x Poverty line
	1.5 x Poverty line
	3 x Poverty line
7 **Employment status**	Formal employment
	Informal wage earner
	Informal self-employed
	3 weeks unemployed
	9 months unemployed
8 **I receive social aid from the government**	Yes, receives income transfers
	Not a beneficiary
9 **The electrical service company in the area is...**	Public
	Private
	Non-profit organization

Source: Adapted from López Cariboni (2017).

The design assumes that public tolerance towards irregular energy consumption may vary depending on the income of irregular users, their area of residence, the number of children, their level of education, employment status, and other aspects related to their levels of social exclusion and prospects for upward mobility. This approach makes it possible to study preferences that can be multidimensional and to estimate the contribution of each attribute to the change in demand due to the application of penalties. In that sense, an amount of interest is the average marginal component effect (AMCE), which represents the marginal effect of the attribute of interest averaged over the joint distribution of the remaining attributes (Hainmueller et al., 2014). Attribute values are randomized based on uniform assignment, while the order of dimensions is randomized at the respondent level to avoid order bias. Table 9.2 shows an example of the table provided to the interviewees, who were instructed beforehand as follows:

Imagine that you are the person in the government who has to decide how to act in different cases of users who consume electricity illegally, either because they are informally connected to the grid or because they have altered their electricity consumption meter. Below we present different profiles of irregular users of the electric power service. For each pair of users, please compare and indicate what action the government should take and your opinions on it.

After showing each pair of profiles, the questions measure the demand for state tolerance or flexibility by asking the following question: “What measures would you take with each of these two irregular users of electricity?” To estimate the results, the options “no action” and “send a warning letter” are coded as tolerance. The remaining two options, namely “cutting the irregular connection” and “cutting the irregular connection together with applying a financial penalty,” are coded as sanction allocation. The question is not forced, to the extent that respondents are not asked to choose between profiles but rather to respond independently for each one.

The results for each country are reported in figure 9.1. Starting with income level coefficients, we plot the average effect of changing from “0.5 × poverty line” (reference category) to, for example, “1 × poverty line,” over the probability of choosing an irregular user for a permissive or tolerant action (where the average is defined over the distribution of the other attributes and across the entire sample). Note that the income of irregular users is negatively related to the demand for state tolerance in all four countries. A change in the income of beneficiaries of informal transfers that allows for them to escape poverty (i.e., from 0.5 to 1, 1.5, and 3 times the poverty line) strongly reduces the probability that respondents will choose a non-coercive action.

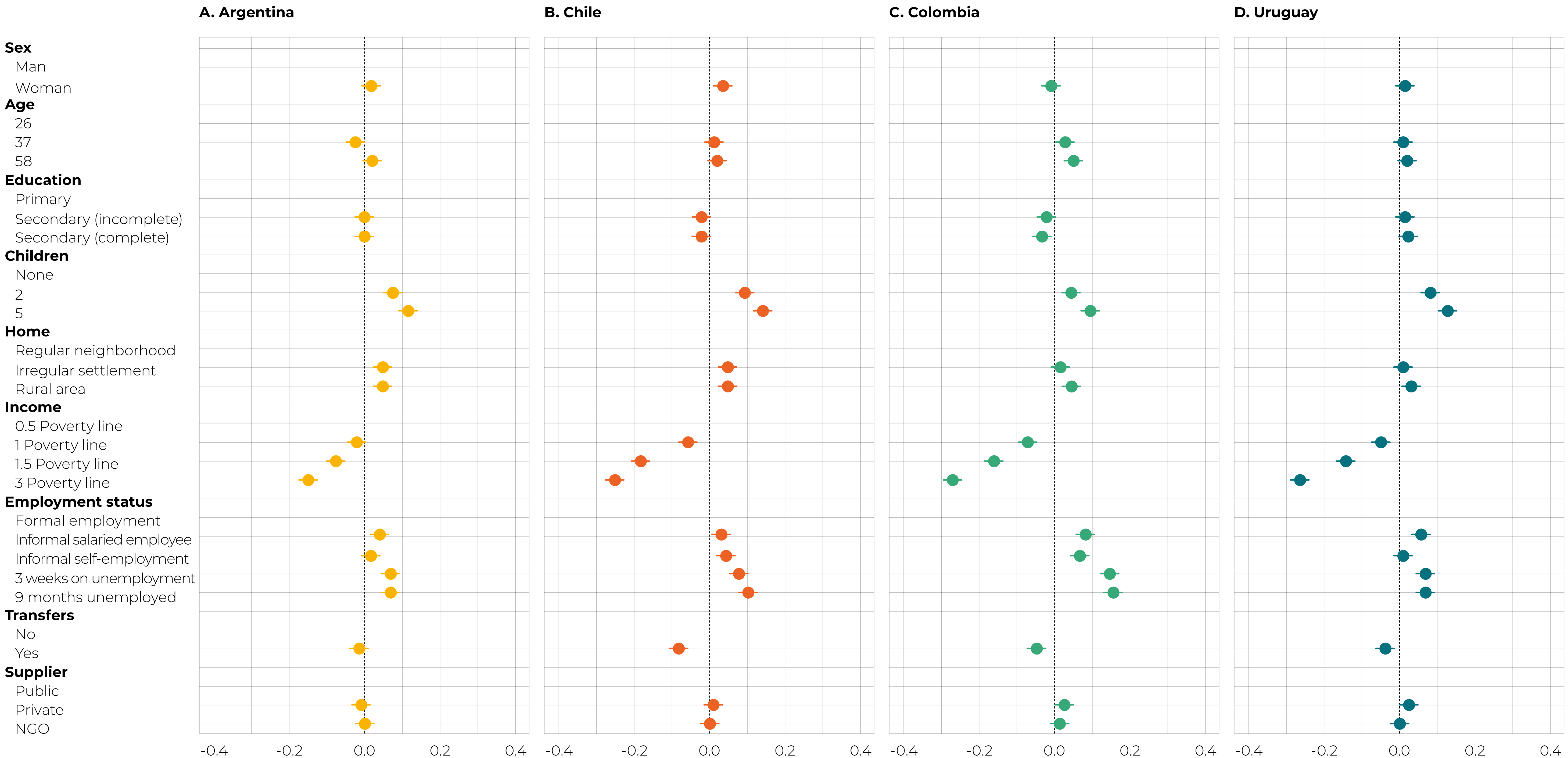
Table 9.2 Comparison of the experiment carried out based on paired profiles (Argentina)

Scenario 1 of 6

	Irregular user 1	Irregular user 2
1 **Place of residence**	Informal settlement or slum	Informal settlement or slum
2 **Employment status**	Unemployed for more than 11 months	Salaried work, without social rights (employer does not contribute to social security)
3 **Monthly income (in Argentine pesos)**	$1,900 (one thousand nine hundred)	$12,300 (twelve thousand three hundred)
4 **The electrical service company in the area is a...**	Private company	Private company
5 **Sex**	Man	Man
6 **Receives help from government social programs**	Does not receive	Yes, receives income transfers
7 **Minor dependent children**	2 sons	Does not have
8 **Age**	58 years	58 years
9 **Level of education**	3rd. year secondary	Completed secondary

Source: Adapted from López Cariboni (2017).

Figure 9.1 Effect of irregular user attributes on the assignment of state tolerance



Source: Adapted from López Cariboni (2017).

An added implication of this preference structure is that a relative increase in the number of low-income people should correlate with greater support for state flexibility toward non-beneficiary sectors. This corresponds to the evidence that informal transfers are countercyclical (López Cariboni, 2019), which suggests that, in times of crisis, politicians in developing democracies respond to such preferences. The same idea takes shape when analyzing the effects of unemployment and labor informality on support for flexibility. As can be seen in the results of Figure 9.1, groups excluded from the labor market, such as the unemployed and those who work informally, are tolerated significantly more than offenders who have a formal job.

A second implication of these results is that pronounced preferences for allocating state flexibility in favor of the poorest could contradict the logic of selfish income redistribution that predicts conflict between social classes. This means that progressive preferences for targeting informal transfers are inconsistent with the assumptions underlying the distribution model proposed by Holland (2015). In this sense, the preferences of groups not benefiting from such transfers may be guided by other aspects such as the positive externalities implied by universal access or the vision of access to energy as a matter of rights (Burgess *et al.*, 2020).

Still, selfish material concerns may underlie these preferences but result from different mechanisms. When weighing the options, the possibility cannot be ruled out that middle- and upper-class actors conclude that transfers are a less costly solution in distributional terms than formalization policies. In this sense, state permissiveness would imply ensuring access to energy without assuming the substantial cost of neighborhood improvement projects and broad policies for formalizing housing and access to services.

Other results, such as those related to sex, age, user education level, and the type of company providing the service, reflect rather small effects. However, the number of dependent children strongly increases their tolerance for irregular energy consumption. Furthermore, the profiles of irregular users who live in areas of irregular settlements and rural areas (where there is often no service provision) are more likely to be chosen to allocate non-penalty measures than those who live in residential areas. Finally, irregular users who receive social transfers are penalized with more coercive actions. This suggests that citizens consider informal transfers substitutes for formal social protection. To the extent that truncated welfare states do not protect the poorest, preferences for informal redistribution can be strengthened.

9.4 Ideological preferences for informal redistribution

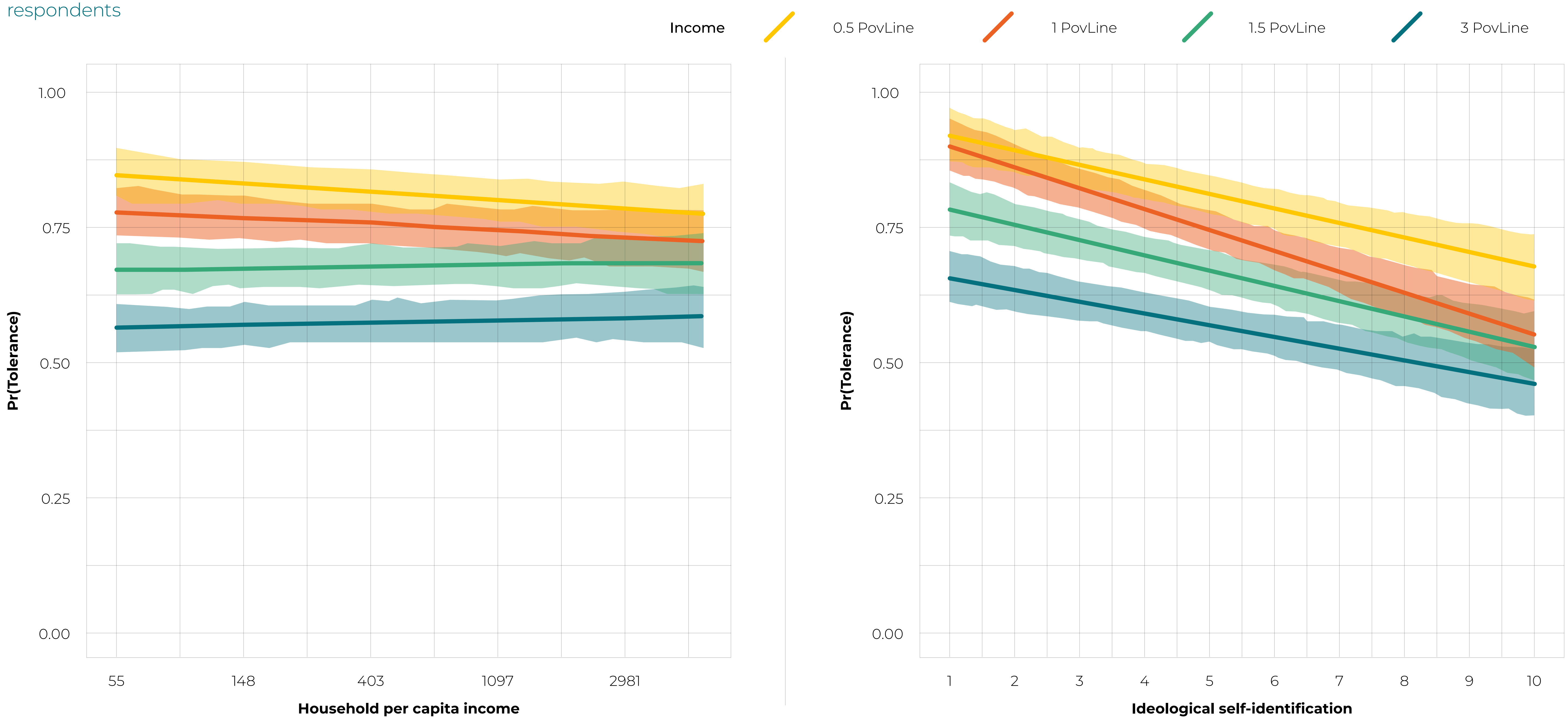
To evaluate the results in more detail, López Cariboni (2017) analyzes the heterogeneous effects through two relevant characteristics of the interviewees: income and ideological self-identification. Income is an important factor here because it helps more specifically evaluate class divisions regarding the demand for state permissiveness. On the other hand, the literature relates redistribution preferences with ideology and notions of justice and entitlement.

The last branch of research on distributive preferences states that individuals support greater redistribution when they believe that the reason for poverty is social injustice and not a lack of effort. Beliefs about an "unjust world" are consistent with the idea that "luck" determines income. These perceptions are believed to be an important reason for people to support the welfare state and fiscal redistribution (Alesina, Glaeser, and Sacerdote, 2001; Alesina and Giuliano, 2009; Benabou and Tirole, 2006). This literature also provides a mechanism that links collective beliefs about entitledness to political ideologies. Right-wing and left-wing individuals differ in that they have different perceptions of the same reality. People on the right tend to be more optimistic about potential gains from the effort, whereas those on the left have more pessimistic perceptions. The former believes in a just world and tends to think that people get what they deserve; hence, there is a greater stigma toward low-income people (Benabou and Tirole, 2006). According to the literature, right-wing individuals are more likely to stigmatize people experiencing poverty by blaming them for their condition.

In contexts where the welfare state mainly protects the middle class—the case of Latin American countries—people on the left may support progressive informal transfers because their perceptions of justice and preferences do not translate well into formal redistribution channels. A simulation-based analysis such as that suggested by King, Tomz, and Wittenberg (2000) helps interpret the interaction between the entry of hypothetical profiles of irregular users and the individual characteristics of the respondents. The left panel of Figure 9.2 simulates the expected values supporting state flexibility (non-sanctioning actions) for each level of experimental treatment (income of irregular user profiles) observed through the per capita income of each respondent's household. The exercise shows no substantial evidence that income is a moderating factor in the progressivity with which they allocate or focus on informal transfers. For example, tolerance towards poorer irregular users decreases marginally as respondent income increases, while tolerance towards non-poor irregular users increases slowly with respondent income. This finding suggests that the distributional conflict model between income groups lacks strong empirical support.

However, the shift from extreme left to extreme right substantially decreases the probability of choosing a non-sanctioning action. Furthermore, as shown in the right panel of Figure 9.2, individuals who identify as left-wing only significantly reduce their tolerance for informality when the irregular user increases their income above the poverty line. Meanwhile, right-wing respondents react more quickly to income increases for profiles that are below the poverty line (0.5 × poverty line)..

Figure 9.2 Support for irregular energy consumption through the income (treatment) of irregular users, observed for different income levels and ideology of respondents



Source: Author's own estimates.

Note: The figure displays on the ordinate axis the logarithm of transmission and distribution losses, while the abscissa axis measures the logarithm of population density.

9.5 Conclusions

In order to advance the understanding of the challenges and opportunities inherent to the region's electricity sector, it is essential to address one of its most complex and key aspects: tolerance of electricity losses. This chapter analyzed the causes of social tolerance of irregular electricity consumption to shed light on the foundations of the political economy of energy losses in the sector. The literature reviewed, and the empirical evidence presented shows that the absence of a progressive social policy that addresses the informal sector is related to social tolerance of losses and encourages informal transfers.

When the strict application of property rights rules entails a significant social cost—such as making it impossible for the most impoverished in a population to access basic services—citizens face the dilemma created by their notions of social justice and their preferences for law enforcement. However, the evidence in the region shows that preferences are progressive in the sense that the demand for state permissiveness is accentuated when its beneficiaries are people who face adverse income shocks or are in contexts of social exclusion.

The evidence also suggests that the primary source of diversity in these preferences comes from the ideological positions of citizens. People who support greater income redistribution, namely those who view the world as more unfair, show substantially higher support for informal transfers. On the other hand, income differences are not a good predictor of preferences for permissiveness of the irregular use of electric services.

In short, the problems of coverage and progressivity of formal social security and redistribution policies stimulate the demand for informal social policies that are not limited to the sectors benefited by state permissiveness. To the extent that politicians seem to react to such demands, the paradox arises that while they increase efforts to achieve universal access to electricity, there are incentives that could prevent the expansion of formal access to safe and good quality services. LAC faces significant challenges in optimizing the electricity sector. Both governments and electric utility companies must recognize that encouraging informal transfers negatively impacts the efficiency and sustainability of the sector. Simultaneously, this permissiveness is not a substitute for implementing social programs focused on improving the well-being of households with greater social vulnerability.

Chapter 10
Conclusions

Electricity transmission and distribution losses are crucial indicators of the electricity market performance, reflecting the efficiency of energy systems. These losses, which arise from the difference between generated and billed energy, include technical and non-technical elements and provide insights into electric power systems' technical and institutional effectiveness. While some loss is inevitable, excessive loss indicates chronic underinvestment or operational and commercial inefficiencies in the system. High electrical losses arise from a complex interplay of technical, financial, socioeconomic, regulatory, and political factors, often extending beyond the scope of corrective actions that electric utility companies alone can undertake, thereby significantly influencing energy markets.

The prevalence of electricity loss in Latin America and the Caribbean (LAC) region is a persistent challenge, significantly deviating from global standards. Over the past three decades, the region has recorded electricity losses of approximately 17% of the generated energy, a rate that triples that of OECD member countries. The economic impact is considerable, with annual costs for distribution companies ranging between USD 9.6 billion and USD 16.6 billion, equivalent to 0.19% to 0.33% of the regional GDP. Addressing this challenge is critical to economic efficiency, infrastructure quality, and environmental sustainability.

Reducing and controlling electrical losses is essential for establishing sustainable electricity markets, considering both the economic and environmental factors. The complexity of this issue and its external repercussions necessitate interventions aligned with various Sustainable Development Goals (SDGs). High levels of electrical losses compromise the financial viability of utilities, impacting both the maintenance and expansion of infrastructure and negatively affecting the quality of electrical services. This, in turn, affects economic competitiveness and poses reliability challenges for vulnerable groups. Moreover, losses increase greenhouse gas emissions because unbilled energy encourages excessive consumption. Therefore, effectively addressing electrical losses is vital for a successful energy transition in the LAC region, in line with the broader goals of sustainability and environmental responsibility.

Latin America and the Caribbean (LAC) region faces an endemic situation of electrical losses, emerging as a primary challenge in the electricity sector. Specifically, in 2019, losses exceeding a 10% threshold amounted to 120 Terawatt-hours (TWh), surpassing the losses in both middle- and high-income countries globally. This issue is not confined to a few countries within the region; it affects 22 of the 26 countries analyzed, proving to be a systemic challenge that requires a comprehensive regional solution. Even in countries where losses are relatively low, significant disparities exist among electric utility companies operating in different areas, highlighting the complexity and magnitude of this issue.

The economic implications of these losses are profound, with distribution companies facing annual costs equal to 0.19%–0.33% of the region's GDP. To put this in perspective, these financial impacts align with the major social programs in the region. For instance, electrical losses in Brazil represent over two-thirds of the budget allocated to the "Bolsa Familia" program. This situation directly threatens economic efficiency, making it imperative to address infrastructure investment deficits. It is estimated that a minimum annual investment of USD 48 billion is required in LAC to ensure universal access to electricity and advance decarbonization over the next decade.

Electrical losses also have a significant environmental impact, contributing to greenhouse gas emissions and hindering sustainable energy practices. These losses result in 5–6 million tons of CO_2 emissions annually, equating to a social cost of $ 320 million USD. The emissions from these losses surpassed those avoided by solar energy use in 2019. This highlights the need to control and reduce electrical losses as part of a broader climate change mitigation strategy, emphasizing the link between energy efficiency, environmental sustainability, and regional commitments to climate change mitigation.

Addressing the electrical losses in the LAC region requires careful consideration of context-specific policy measures. Recognizing regional heterogeneity is critical because no single solution fits all contexts. The complex interplay of institutional frameworks, financial constraints of electric utilities, and unique operational circumstances in each country necessitates nuanced, localized strategies. Effective loss reduction demands sustained political commitment in the long term, ensuring consistency in the measures required to achieve goals. Successful initiatives have been implemented over extended periods spanning several government cycles, fostering a culture of responsibility to pay for electricity services.

The social dimensions of loss reduction policies are crucial. There is a clear social demand for regularized electrical services involving improvements in service quality and willingness to pay for these improvements. Integrating strategies that prioritize service quality with loss reduction can incentivize users to accept potential increases in electricity prices. Transparent regulatory frameworks are essential for providing incentives for the efficient operation of electric utilities. Urgent investments in infrastructure are necessary to modernize the electric power system, with private participation playing a key role in funding these initiatives. The digitalisation of the electricity sector is strategic, enabling real-time data collection and management, enhancing efficiency, and supporting loss-reduction initiatives. A holistic policy design approach involves intersectoral coordination, social awareness programs, and best management practices in electric utilities, collectively paving the way for effective, sustainable, and socially responsible loss-reduction strategies in the LAC region.

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Appendix

Appendix 1. Compilation of statements on the monetary value of losses of electric utility companies

Country	Cost of power losses (millions of USD)	Value of electricity losses (Millions of 2019 U.S. Dollars)	Year	Source
Brazil	$4000	$4,690	2010	Brazil News Website (05/31/2011)
	$2400	$2,503	2017	Non-technical losses [PA5]. Baffi et al (2018).
Colombia	$70	$82	2010	Portafolio News (08/16/2011)
	$24	$27	2011	Non-technical losses. Ventura *et al.* (2020)
Dominican Republic	$540	$593	2013	El Día News (03/19/2014)
Ecuador	$230	$261	2011	Ecuador Inmediato News (04/28/2012)
Guatemala	$30	$33	2013	Ministry of Energy and Mines, Republic of Guatemala (03/06/2014)
Honduras	$462	$507	2013	CB24 News (04/15/2014)
	$134	$117	2022	Bloomberglinea (7/11/2022)
Jamaica	$43	$47	2013	Jamaica Observer News (05/15/2014) and Lewis (2015)
	$301.6	$315	2017	
Mexico	$5000	$4,717	2021	BNamericas August/17/2021. Includes technical and non-technical losses.
Nicaragua	$110	$117	2016	Confidencial (Nicaragua, March/26/2017)
	$50	$56	2012	Confidencial News (Nicaragua 03/04/2012)
Panama	$20	$22	2013	Panama América News (02/22/2014)
	$15-30	$56	2018	El Siglo (Sept/23/2019)
Paraguay	$180	$22	2012	Petrolpost News (Asunción 09/03/2012)
	$187.5	$20	2021	ABC (Paraguay May/17/2022)
Uruguay	$144	$200	2021	The Observer (January/24/2021)
	$60	$177	2013	El País News (01/26/2014)
Venezuela	$600	$136	2011	El Mundo News (05/22/2012)
Total		**$9,400 - 12,300**		

Source: Prepared by the authors

Appendix 2. Incentive-based regulations to reduce electricity losses in Europe[78]

The incentives strategy for managing and minimizing electricity loss has also been implemented in Europe, albeit on a limited scale. The 2020 report from the Council of European Energy Regulators (CEER) found that 20 of the 36 countries have implemented incentives to reduce distribution losses, while others plan to introduce them in the future. Regarding transmission, CEER (2020) found that incentive-based regulations only applied to 13 of the 36 countries. An analysis of current regulatory practices illustrates the following methods for dealing with energy losses in distribution networks:

1. The Czech Republic implemented a correction factor for previously estimated loss values, where the actual annual losses in the network adjust the relevant regulations. The difference between regulatory and actual losses (if the latter are less than the former) is multiplied by the price of the losses, and this sum is divided equally between the supplier and its customers. There has been no significant impact yet, but these incentives were introduced only in 2016, and not enough time has passed to evaluate them properly.

2. In Italy, an incentive mechanism has been applied to reduce losses in distribution networks. This allows the supplier to be rewarded or penalized whenever losses are below or above the pre-established target level (standard losses). This mechanism is applied annually based on data obtained from the conciliation process.

3. In Montenegro, non-technical losses are not recognized as part of the grid rates, which generates an intrinsic motivation for grid operators to reduce them. In addition, the rate of return on planned investments considers reducing technical losses.

4. Denmark introduced a relatively new system in 2018 to provide incentives for loss reduction. Providers receive an amount that covers their cost-related grid losses as part of the revenue cap. The amount is estimated based on the historical relationship between the loss level and the amount of energy supplied. Thus, suppliers are incentivized to become more efficient, as this brings economic benefits.

5. Greece introduced a new incentive plan that had not yet been developed. Its distribution network code includes provisions for a penalty/reward scheme to incentivize suppliers to control network loss.

78. See CEER (2020).

6 In Sweden, a new revenue cap regulation system was enacted in 2020. Among other factors, the incentive scheme of this regulation considers a reduction in grid losses.

7 In the Slovak Republic, the National Regulatory Authority (NRA) sets the maximum allowable loss (in %) for each voltage level, which is reduced annually by an efficiency factor using an officially determined formula. Suppliers are encouraged to invest in a distribution system that increases energy efficiency and reduces energy losses through this regulatory intervention.

8 In Slovenia, an incentive for transmission and distribution system operators was introduced into the new 2019–2021 regulatory period methodology. An incentive is applied if the price reached for the purchase of electricity to cover losses is lower than the regulator's reference price.

An analysis of current regulatory practices reveals the following methods for the treatment of electricity losses in transmission grids:

1 In Denmark, the transmission system operator is governed by a cost-coverage regulatory framework that sets targets to reduce the cost of grid losses. The current target is a reduction equivalent to DKK 50 million over eight years.

2 In Hungary, the transmission grid operator is incentivized to reduce both the level of losses and loss acquisition costs. In the initial year of each four-year price regulation period, both the accepted level of losses (in %) and the accepted price (per kWh) were set by the National Regulatory Authority (NRA). In the remaining years, the accepted level was reduced by a predefined percentage. Grid charges do not fully cover the difference between the actual cost and predetermined network loss acquisition cost.

3 In Montenegro, the rate of return of the transmission system operator on planned investments depends on reducing technical losses.

4 Kosovo uses loss-reduction incentives through multiyear rate reviews. If the cost of losses is below the specified target, the transmission system operator may maintain the difference between the actual cost and the target loss cost as additional profit.

5 In the Netherlands, to incentivize the transmission system operator to acquire energy that covers losses more efficiently, it is partially reimbursed for the difference between the realized costs (in year t-2) and the estimated purchase costs (in the current year). If the difference between the realized and estimated purchase costs does not exceed 20%, the refund is equal to 75% of the difference. Any costs beyond this are fully passed on, limiting the operator's risk.

6 In Poland, the level of losses is set in the rate using historical data combined with an efficiency improvement factor. If the transmission system operator achieves higher efficiency (reduced losses), profits are allowed in the amount of that difference.

7 Countries such as Georgia, Norway, Serbia, Slovakia, Slovenia, and Sweden apply the same regulatory treatment for transmission and distribution losses.

Another regulatory instrument to reduce losses to an economically optimal level requires network operators to consider the capitalized value of losses in their investment decisions. The CEER reports that nine countries have such provisions, and eight also require a declaration from network operators on the expected reduction in losses caused by new investments. .

1. In Ireland, annual losses were estimated using energy-flow simulations. They are monetized using a system average marginal price and capitalized, reflecting the present value of the losses (saved or reduced) attributed to the investment.

2. In Latvia, although there is no specific methodology or obligation to consider the capitalized value of losses, the price of losses resulting from the internal policies of the system operator is considered when evaluating new investment decisions.

3. In North Macedonia, network operators are required to explain every investment of over 100,000 euros. The explanation includes an expected reduction in losses, among other things.

4. In Norway, all grid assets with voltage levels above 22 kV require a license, and network losses are part of the assessment by licensing authorities. Additionally, loss calculations are required if these are significant factors in investment decisions. There are no licensing requirements for voltage levels below 22 kV; however, grid operators still have an incentive, albeit indirectly, to consider the value of losses in investment decisions.

5. In Kosovo, grid operators are required to prepare annual loss reduction plans. The corresponding investments are presented in five-year investment development plans.

6. In Montenegro, grid operators must estimate the loss reduction caused by investment.

7. In Portugal, estimated loss reduction is a criterion for selecting investment decisions.

Anexo 3. Methodology for estimating electricity losses

In addition to the assumptions and procedures summarized in Chapter 6, the calculation of electricity losses in this publication relies on some differences with respect to the studies by Surana and Jordaan (2019) and IEA (2020). These differences include:

1. **Sources of information:** For most countries these are official bodies (rather than the International Energy Agency). In some cases, such as in Paraguay and the Dominican Republic, there may be relevant differences between the losses reported by the IEA and those of official national agencies. Energy specialists from each country validated the most appropriate sources of information..

2. **Emission factors:** In this exercise we have taken those from the IFI Technical Working Group on GHG Accounting (on-grid) system. Unlike the life cycle assessment (LCA) for energy generation used by Surana and Jordaan (2019), the approach used in this publication more directly captures the de facto carbon footprint of each electrical mix. This approach also considers both the operating margin and any recently built plants. In this way, the emission factor (EF) used implicitly captures the efficiency of the generation park..

3. The approach to addressing uncertainty in the results is also different from that used by Jordaan and Suana (2019). Instead of applying Monte Carlo analysis to evaluate the effect of the sensitivity of the assumed parameters, we identified stress situations for the estimated net benefit. Thus, the present approach identifies a conservative baseline case and a case that stresses estimations to the point of returning a negative social rate of return.

Appendix 4.
Studies on willingness to pay for electricity attributes

Authors (Year)	Method	Sample	Attributes
Blass, Lach, Manski (2010)	DCE, MXL	Israel N: 557 (urban) Interview	Reliability: frequency, duration, notification, information services and price.
Hensher, Shore and Train (2014)	DCE, MXL	Canberra, Australia. N: 240 (urban) By mail	Reliability: frequency, duration, timeliness, notification, information services and price. Quality: frequency, voltage and price.
Carlsson, Martinson and Kay (2011)	Contingent valuation (open)	Sweden N: 1518 (before a storm) N: 416 (after a storm) By mail	Number of outages, duration of outage, price (open). Includes questionnaires with 212 control households and 204 treatment households.
Abdullah and Mariel (2010)	DCE, MXL	Kisumu, Kenya 200 rural homes By mail	Price, number of outages, duration of outage, type of provider
Morrison and Nalder (2009)	DCE, MXL	New South Wales, Sydney, Australia N: 350 companies By mail	% change in bill, frequency of blackouts, duration of blackouts, blackouts and surges, notice, telephone waiting time.
Carlsson and Martinson (2008)	DCE, MXL	Sweden N: 425 urban homes By mail	Price, number of blackouts, duration of the blackout.
Carlsson and Martinson (2007)	Contingent valuation (open)	Sweden N: 1488 By mail	Price, number of blackouts, duration of the blackout.
Yu, Jamasb and Pollit (2009)	Matched profile analysis	United Kingdom. N: 2118 homes; 1965 urban and rural businesses, Ofgem data, 2004	% of bill, number of blackouts, duration of blackout.

Note: DCE=Discrete Choice Experiments ; MXL= Mixed Logit.

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