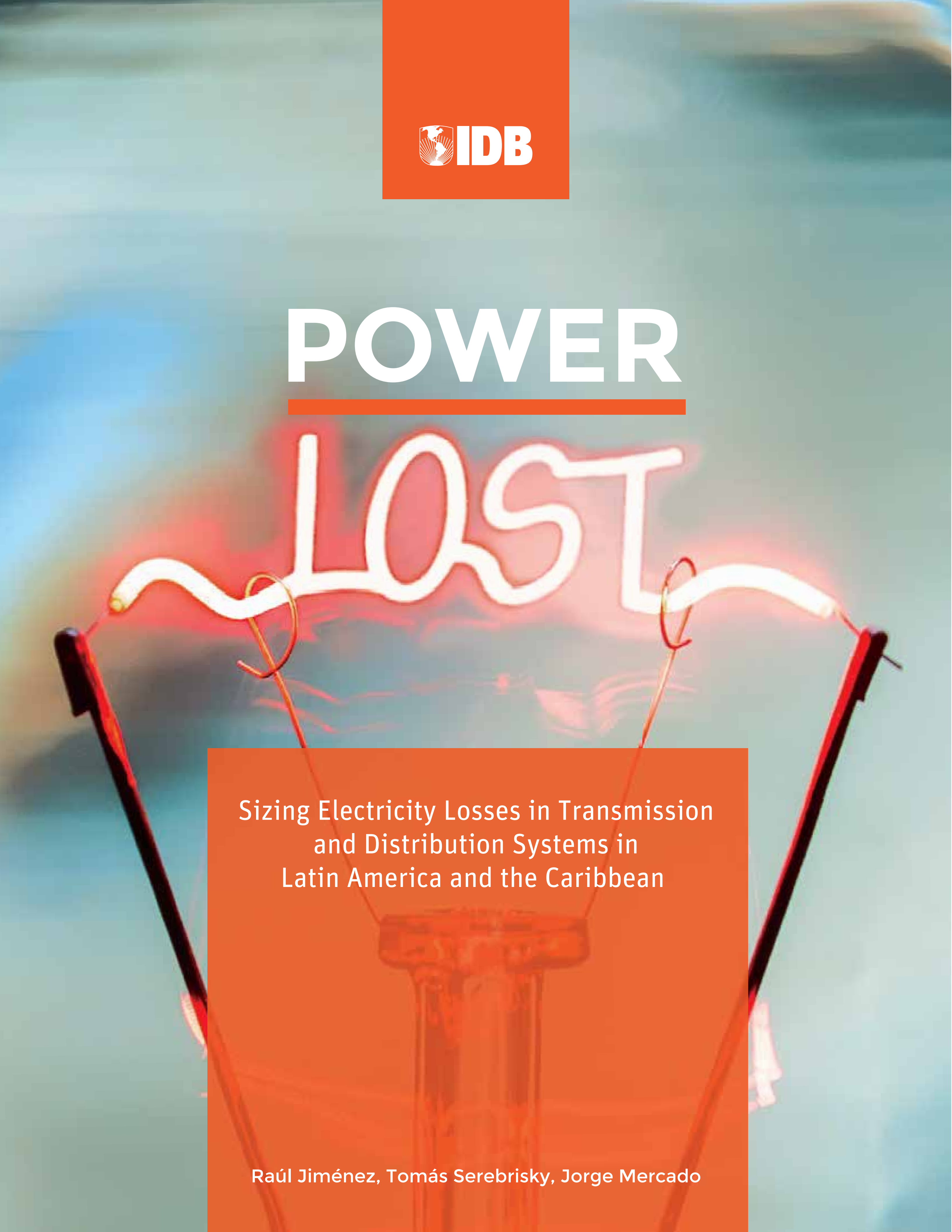

IDB

POWER LOST

Sizing Electricity Losses in Transmission and Distribution Systems in Latin America and the Caribbean

Raúl Jiménez, Tomás Serebrisky, Jorge Mercado

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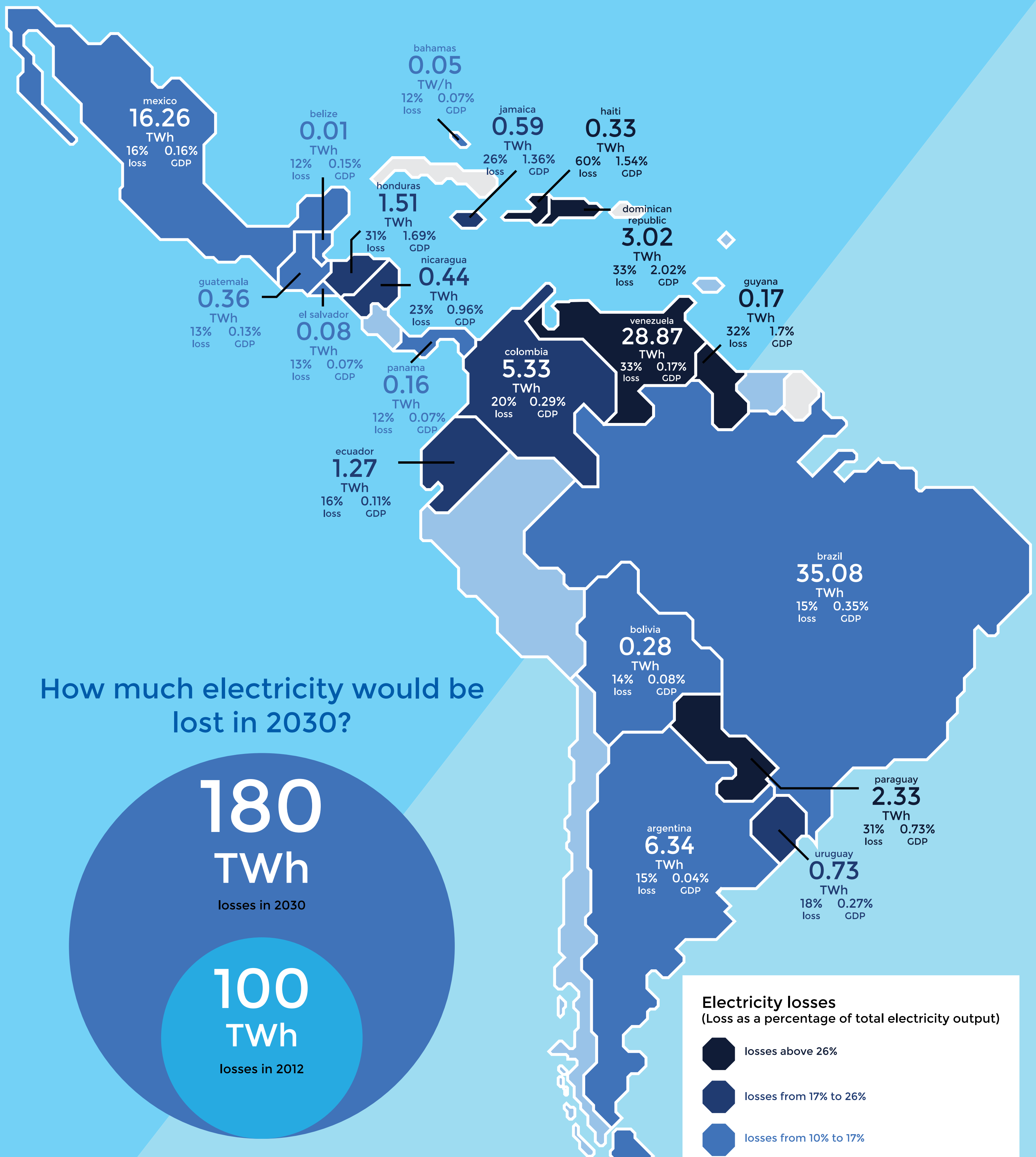
How much electricity would be lost in 2030?



Electricity losses
(Loss as a percentage of total electricity output)

- losses above 26%
- losses from 17% to 26%
- losses from 10% to 17%
- losses below 10%

Note: TWh refers to those losses after discounting 10% of electricity output.

%GDP estimated for countries with losses above 10% of electricity output

Information as of 2012.

World electricity losses are around 290 TWh

This is equivalent to the electricity consumed by Mexico and Peru in 2013.

Each year,

17%

of electricity generated is lost in LAC, higher than the loss levels of OECD countries (6%) or low-income countries (15%).

US$11 – US$17 BILLION

Electricity losses represent between US$11 billion and US$17 billion as of 2012 equivalent to as much as 0.3% of the region's GDP.

If the current situation continues in LAC, electricity losses in

2030

could be the equivalent of two times the annual electricity generation of Itaipu.

A third of world electricity losses occur in LAC,which is the equivalent of two times the annual electricity consumption of Peru.

100 TWh

20 of 26

LAC countries have losses above 10% of total electricity output; 12 of 26 LAC countries have losses above 17%.

LAC's electricity losses in

2012

matched the average annual electricity generation of the hydroelectric station Itaipu.

80%

of electricity losses in

LAC occur in the distribution subsector.

Contents

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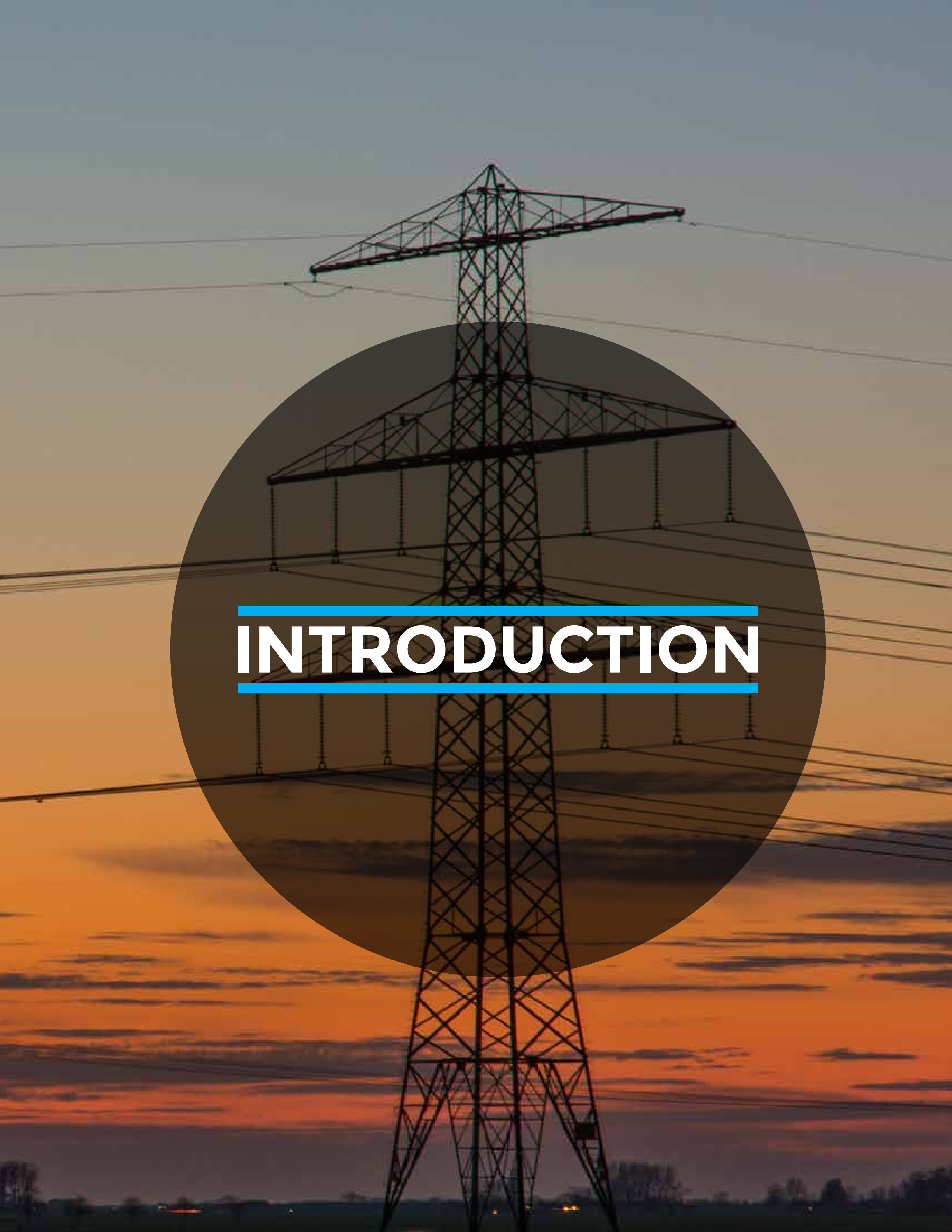
INTRODUCTION



Electricity loss is a key component in measuring the efficiency and financial sustainability of the power sector. It represents the difference between the amount of electricity that enters the network and the amount that is delivered to end-users, reflecting the degree of productivity of transmission and distribution systems. Losses also include the electricity delivered but not billed, directly translating into financial losses and, to a great extent, representing an indicator of the operational soundness of utilities.

Reducing electricity losses could help achieve the goal of universal access to electricity services. Lower electricity losses are associated with greater financial sustainability of utilities, as additional revenues increase cost recovery, enhance the capitalization of the power sector, and improve the sector's capacity to invest. In addition, lower electricity losses can potentially contribute to reducing air pollution emissions, as well as to decreasing electricity tariffs for consumers. Further, increasing electricity bill collection not only increases revenue, but it also sends a market signal that discourages over-consumption and incentivizes energy conservation practices.

The main objective of this Brief on electricity losses in transmission and distribution systems is to map the severity of the problem across LAC countries, therefore contributing to a more systematic monitoring of electricity losses in the region. Despite some efforts to improve the performance of the electricity sector, the levels of electricity losses in Latin America and the Caribbean (LAC) have remained above benchmark references for several decades (see BJM, 2013). According to estimates presented in this Brief, electricity losses in LAC (around 17 percent on average in 2007-2011), are greater than several low-income countries in developing regions, and comparable to levels seen in the United States in 1929. As a reference, electricity losses in high-income countries of the Organization for Economic Cooperation and Development (OECD) - mainly technical losses from the transportation process in relatively efficient systems - have fluctuated on average between 6 and 8 percent of total electricity output.

Electricity losses represent a widespread and costly problem in the region. Half of LAC countries have electricity losses above the 17 percent average. A rough estimate of the annual financial cost of these losses totals between US$11 and US$17 billion (in 2012, representing between 0.19 to 0.3 percent of Latin American GDP). As this figure reflects neither subsidized electricity prices nor the environmental costs of such losses, it likely represents an underestimation. Even so, it poses a huge financial burden on utilities and a significant opportunity cost for society. For example, the estimated annual cost of electricity losses in Mexico is around US$4.4 billion (CICM, 2011), approximately equal to the investment in the country's *Oportunidades* program, the largest social program in Latin America. For some countries, losses total one-third of the electricity delivered to end-users, eliminating any chance for power systems to be financially sustainable.

Despite the important economic consequences of electricity losses, there is currently no systematic monitoring of electricity losses in LAC that allows identifying its sources or keeping track of countries' performance. In this context, and as part of a programmatic knowledge agenda in the framework of the IDB's Infrastructure Strategy, this Brief complements previous efforts by the Bank and relevant regional institutions to quantify, monitor and address the problem of electricity losses in Latin America and the Caribbean.

The first section provides an overall classification and definition of electricity losses. The next two sections estimate the degree of electricity losses, focusing on cross-country and cross-region performance over time, and by electricity subsector. The last section presents some final remarks and suggests future research needs.

1

TAXONOMY OF ELECTRICITY LOSSES

Taxonomy of Electricity Losses

The losses of electricity that occur along the entire chain of a power system serve as a key measure of its efficiency. Broadly speaking, such losses account for the difference between the electricity available for use and what is paid by end-users.[1] When losses occur during transportation, they offer a direct measure of the technical efficiency of the system. When losses are related to nontechnical factors, they reflect the operational efficiency of the utilities.

Definitions of electricity losses vary across countries. **Exhibit 1** shows a simplified power system flowchart useful for setting up our discussion. While this Brief does not address transformation losses, it is nonetheless useful to start with power generation. At this stage, 'inputs' refer to all those elements—such as different type of fuels—that enter the production process of power outputs. At the aggregate level, losses from power transformation and auto-consumption[2] of electricity by generation plants account for approximately two-thirds of total input (International Energy Agency, 2012). It is important to emphasize that the level of efficiency varies based on the size of the plant, its age, and its capacity utilization, and that at the country level, efficiency depends heavily on the electricity mix. For example, generation losses in hydropower systems represent only about one-eighth of total input.

After generation, electricity output enters the transmission system, which is usually composed of high- and medium-voltage networks (≦100 KV). Electricity losses during transmission occur mainly as a result of technical factors, climatological events, and specific geographic conditions. In contrast, once power enters distribution systems that deliver electricity to end-users, losses are a result of both technical and nontechnical factors. This is because distribution (and commercialization) involves several steps in addition to transporting electricity, including connecting, metering, and charging for service. A classification of electricity losses is presented in the next section.

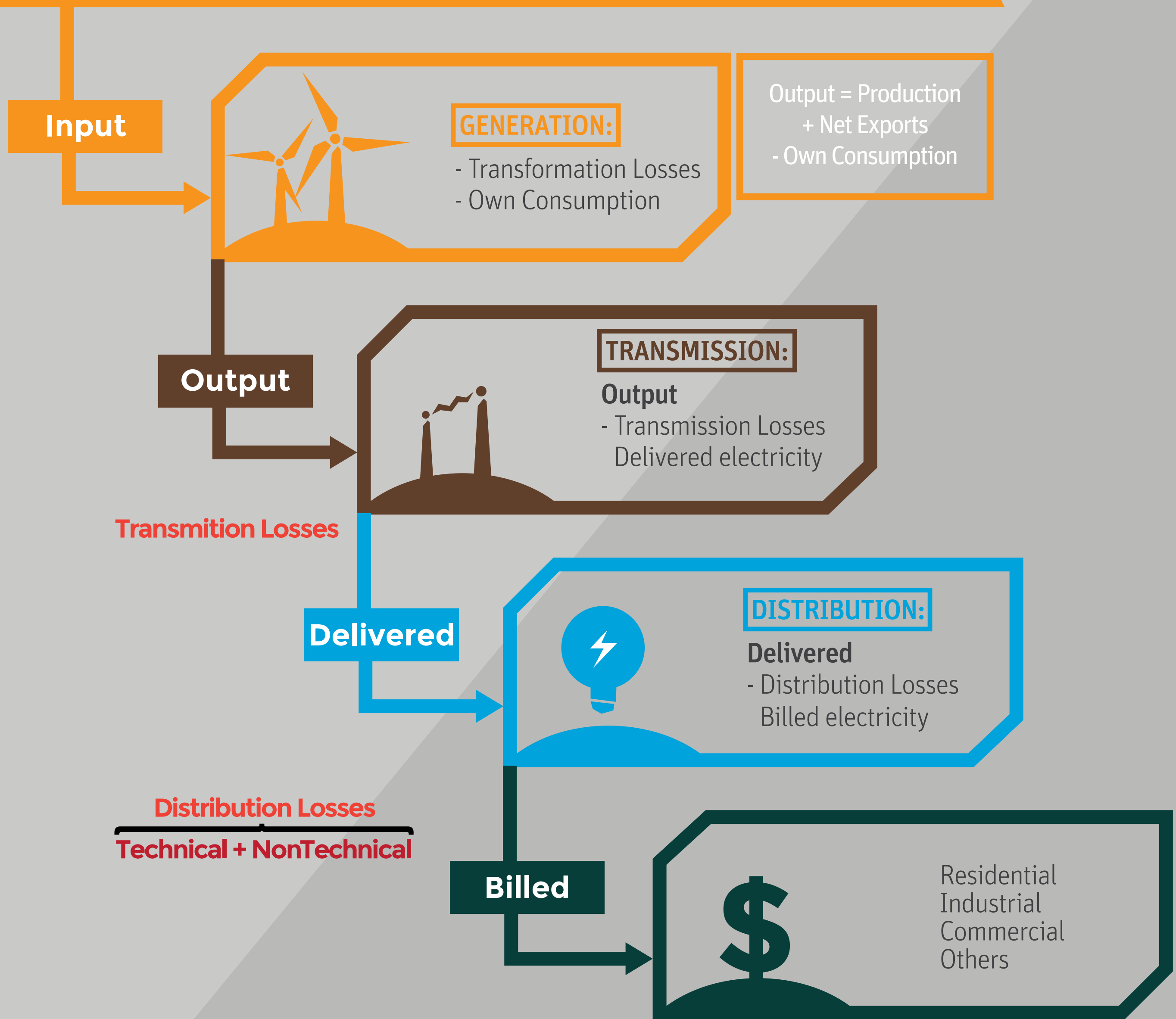
Accounting for the role each subsector—generation, transmission, and distribution—plays in total electricity losses is not always a clear-cut exercise. Specifically, even in countries where transmission is the sole responsibility of specific utilities, in separate business units, actors in the generation and distribution subsectors may also carry out transmission activities. This is the case, for example, in Chile and Peru, where the reporting of electricity transmission also involves power lines owned by the generation and distribution subsectors. On the other hand, the definitions of transmission power lines vary across countries, making it difficult to perform across-the-board comparisons of transmission losses by country. For example, in their classification of transmission; Bolivia, Paraguay, and Nicaragua include lines under 110 KV, which are inherently susceptible to greater technical losses than larger-voltage lines.

1 In this Brief, available electricity refers to the power entering the electricity network, including gross generation, net imports, and isolated production. End-users include residential, industrial, transport, commercial, and other customers.

2 Auto-consumption of electricity refers to energy used for the operation and maintenance of power plants.

Exhibit 1

Losses in Electricity Flow



Source: Prepared by the authors.

Classification of Losses[3]

There are two broad categories of losses encountered in power systems (see Exhibit 2). The first type is technical losses, which occur in transmission and distribution lines, and can be divided into fixed and variable losses:

Fixed technical losses

Fixed technical losses are caused by physical inefficiencies such as hysteresis, Eddy Currents losses in the iron core of transformers, and the corona effect in transmission lines. These losses are proportional to the square of the voltage and are independent of power flow. Since voltage varies relatively little from its nominal value, these losses are treated as a constant that depends mainly on the quality of the line. These types of losses account for between 20 and 40 percent of total technical losses.

Variable technical losses

Variable technical losses happen when power current flows through the lines, cables, and transformers of the network. These are also called load losses, series losses, copper losses, or transport-related losses, and are proportional to the resistance of the branch and to the square of the current in the branch. All things being equal, higher voltage lines tend to produce lower technical losses when looking at the net balance between fixed and variables losses.

Electricity meters are another source of technical losses. Like any other component of the infrastructure of an electricity system, meters are subject to malfunction and inefficiency. As a point of reference, in Great Britain these losses account for a reported 3 percent of total technical losses (Ofgem, 2009).

In this sense, technical losses are inherent to the current transportation and highly associated with the infrastructure characteristics of the power systems. Thus, reductions in this type of losses are considered gains in energy efficiency in the transmission and distribution activities.[4]

Two important considerations can be drawn here with regard to technical losses. First, since the primary component in variable losses is power current, the amount of these losses depends on how much current flow through the system—that is, technical losses tend to go up as load increases, are thus seasonal and can be tempered through demand management. Second, distance from the source as well as the demographic characteristics of the end market partially determine the degree of loss and the cost of delivery, i.e., it is expected that hard-to-reach rural areas with low population density will exhibit more technical losses than urban areas.

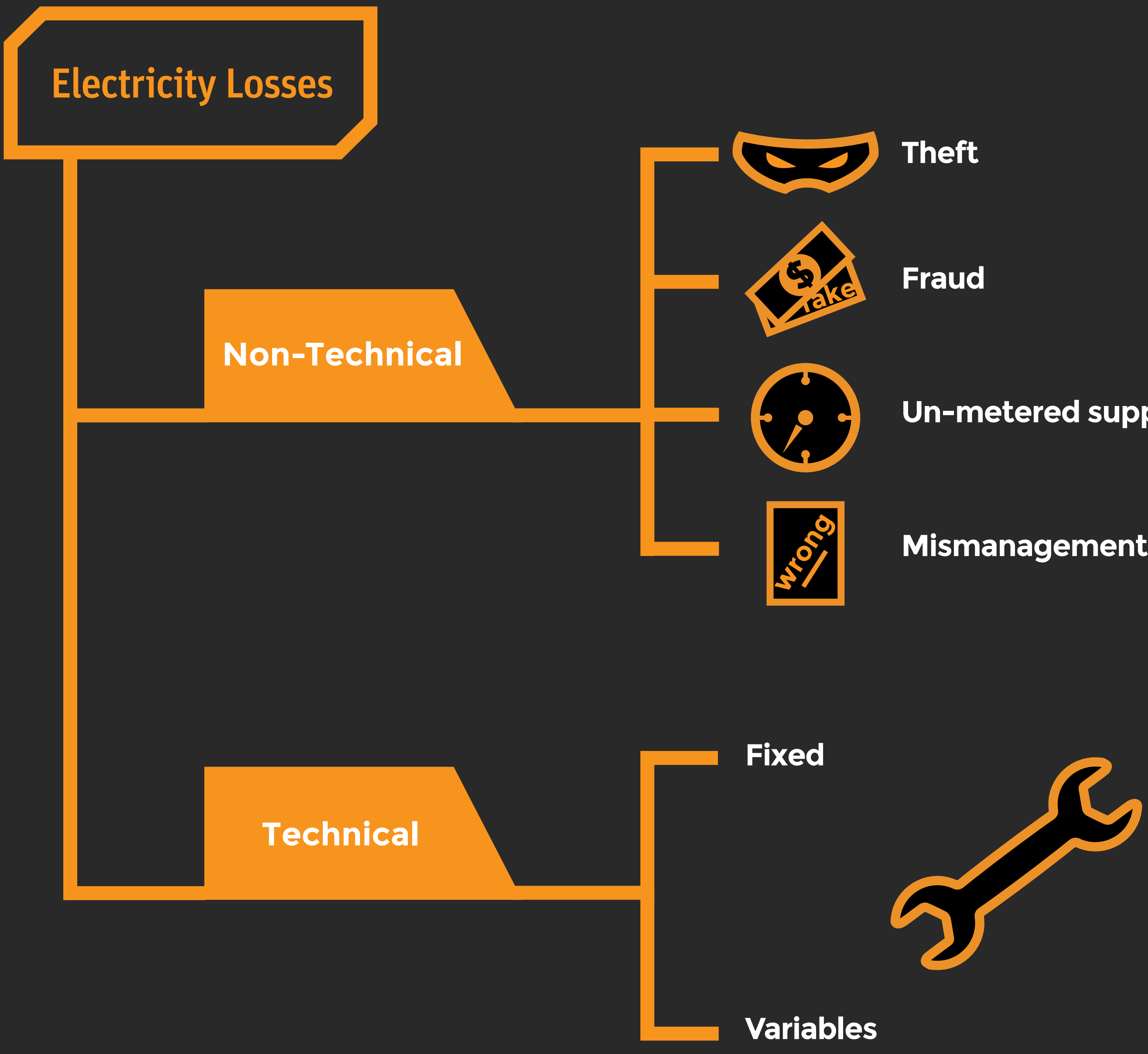
What is the expected level of technical losses? This type of losses depends on many interrelated factors within the system configuration (power line voltage, loads, etc.). However, good practices and international benchmarks refer to figures from high-income developed countries as references. In those countries losses are almost exclusively technical (as opposed to non-technical) and given their proper infrastructure and monitoring systems, they are expected to be minimal. The ratio of electricity losses in high-income countries ranged from 6 to 9 percent over the last three decades (see Exhibit 3).

3 See also Ofgem (2003, 2009) and World Bank (2009).

4 See BBBR (2010) for a detailed analysis of the experience of the Administración Nacional de Usinas y Trasmisiones Eléctricas de Uruguay upgrading the voltage of distribution lines.

Exhibit 2

Taxonomy of Electricity Losses



Source: Prepared by the authors.

The second type of losses is nontechnical, which refers to electricity effectively delivered by a supplier but not paid for by the users, resulting in direct financial losses for the utility. This type of loss is caused by actions external to the power system but internal to overall management of the utility. Depending on the source, these losses can be attributed to:

Theft, referring to energy that is illegally appropriated from the network for users without connection to the grid. These represent illegal or "hung" connections.

Fraud, referring to those users who modify measuring equipment to register lower levels of consumption than are actually used, an illegal practice known as "tampering."

Unmetered supply, which usually includes electricity used for street lighting and traffic bollards (Ofgem, 2009). Additionally, in LAC, there are cases where slums are provided with electricity service but there is no tracking of household consumption.[5]

Mismanagement, which includes miscalculations or errors in accounting and record keeping, as well as lack of proper registration.

For utilities, nontechnical losses are often referred to as commercial losses, since proper metering and billing for electricity is integral to commercial management (World Bank, 2009). Further, it is relevant to note that the listed sources of losses imply some degree of inability of the utilities to measure the electricity delivered at end-user level. That is, utilities have to lose the income of not identified electricity consumption. However, it is also the case that nonpayment (electricity billed but not paid) is also considered a loss, a situation which is attributable to lax enforcement. In other words, although consumption is correctly metered and billed, it is later recorded as a loss because of the utility's low charging capacity.

5 In contrast, countries such as Mexico and Costa Rica have minimum bill schemes that charges for the equivalent of 25-30 kilowatt hours even if household consumption is zero. To the extent that in this case may be charges for electricity that is not delivered, this represents the opposite of nontechnical electricity losses.

Institutional and External Drivers

Proper regulatory and governance schemes should provide adequate signals to promote a reduction in losses. With regard to regulation, a transparent pricing system can incentivize utilities to better manage electricity losses. Countries such as Chile, Colombia, Costa Rica and Peru have set up pricing systems that reward overperformance and penalize underperformance in both transmission and distribution. Similar pricing strategies have been set up in large metropolitan areas in El Salvador, Guatemala, Panama, and Uruguay. For example, under these schemes, the regulator only allows a cap around 7 percent of losses that can be passed on to consumers through electricity tariffs. Utilities must cover all losses above this cap—thus affecting their bottom line.

Independent governance of the utilities is key to providing the required incentives to monitor losses as a way to improve operational soundness. Backed by a proper institutional and regulatory framework, both public and private utilities have managed to reduce losses in countries like Costa Rica and Trinidad and Tobago (publicly-led power systems), and Chile and Peru (private). However, it is still observed higher levels of losses in countries with higher public participation (see BJM, 2013); pointing to the need for mechanisms that promote better performance through ensuring autonomy in the utilities‘ decision-making processes.

A combination of factors external to the performance of the power system may result in theft and fraud. These include rising prices and/or low incomes, which can be permanent or temporary (if for example they are the consequence of an economic crisis). In addition, theft or non-payment can depend on cultural context; customer segments in some localities may not be used to paying for public services. Finally, both could also be a response to low-quality service or poor monitoring by the utilities. In any case, programs aimed at reducing electricity losses must ensure a proper characterization of the target population in order to appropriately address the problem.

Data Availability

For analytical purposes, it would be ideal to assess electricity losses according to their classification as technical or nontechnical, across each phase in the electricity production and delivery chain. This analytical separation would allow for the tracking of key causes of losses and their materiality. However, the heterogeneity of electricity systems and the difficulty of measuring nontechnical losses make it difficult to gather comparable information across countries. This partially explains why in LAC there are no systematic records of losses by type, whether technical or nontechnical or in transmission or distribution.

In light of this analytical difficulty, a regional accounting of losses faces a basic challenge: the availability of consistent and reliable information from each LAC country. For this report, the approach was to develop a country-aggregate estimate of total losses for 26 LAC nations. To obtain this estimate, the final dataset analyzed includes official information from regulators, ministries and the Economic Commission for Latin America and the Caribbean (ECLAC). In order to provide comparisons of LAC with other countries and regions, this dataset was complemented with information reported by Energy Information Administration (EIA). Own estimations were used as a last resort and were based on reliable data from the EIA, official electricity balance sheets, or representative utilities. Other sources of information for electricity prices include the Commission for Regional Energy Integration *(Comisión de Integración Energética Regional – CIER)* and the Latin American Energy Organization (OLADE).

In order to provide comparable data, the information analyzed is calculated as follows:

$$\text{Total Electricity Loss Ratio (L)} = \frac{\text{Transmission Losses + Distribution Losses}}{\text{Output}} = \frac{\text{Output - Billed}}{\text{Output}}$$

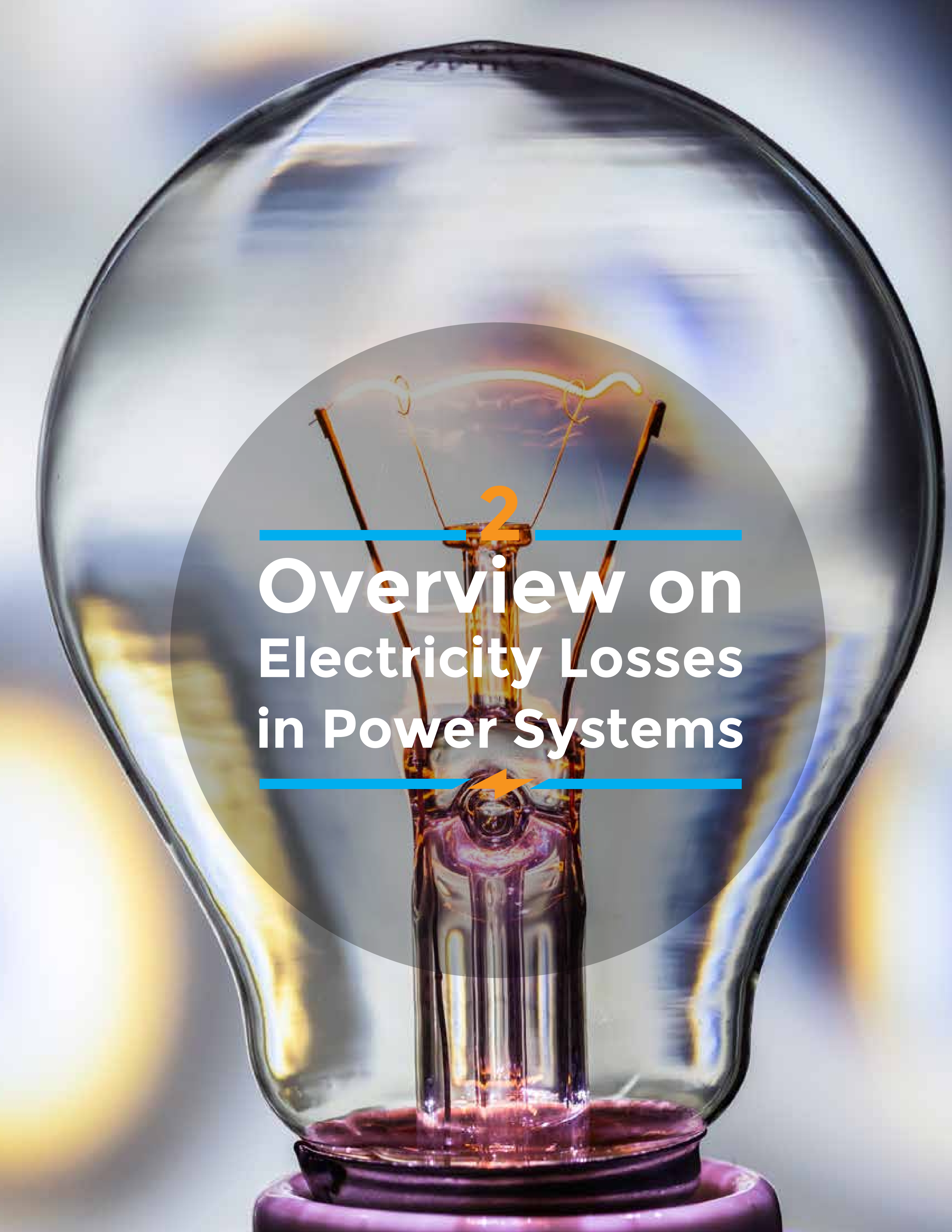
$$\text{Transmission Loss Ratio (TL)} = \frac{\text{Transmission Losses}}{\text{Output}} = \frac{\text{Output - Delivered}}{\text{Output}}$$

$$\text{Distribution Loss Ratio (DL)} = \frac{\text{Distribution Losses}}{\text{Output}} = \frac{\text{Delivered - Billed}}{\text{Output}}$$

$$\text{Technical Distribution Loss Ratio (TDL)} = \frac{\text{Technical Losses}}{\text{Output}}$$

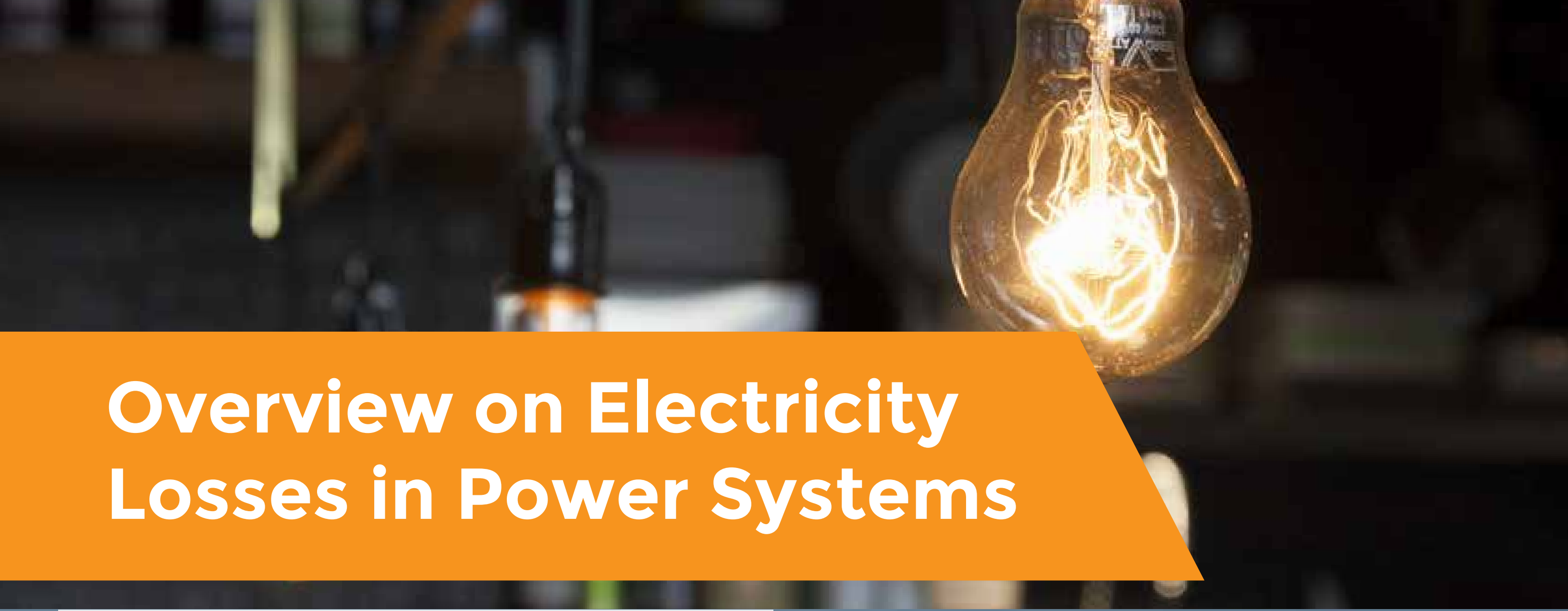
$$\text{Nontechnical Distribution Loss Ratio (NDL)} = \frac{\text{Nontechnical Losses}}{\text{Output}}$$

The final sample includes 140 countries over the period 2007-2012, including 26 from LAC. The countries were classified as LAC and exclusive groups according to their income following the World Bank's World Development Classification. In order to avoid anomalous years, the ratios are calculated as five-year averages. Similarly, in order to avoid over-representation of larger countries, averages are calculated as an average of each country ratio.



2

Overview on Electricity Losses in Power Systems



Overview on Electricity Losses in Power Systems

This section considers the problem of electricity losses in LAC in comparison to other groups of countries, classified by income level and region. A key takeaway is that as a region LAC has one of the highest ratios of electricity losses in the world--a trend that has continuously worsened over the last three decades.

Roughly 17 percent of total electricity produced in LAC is lost in transmission and distribution (average for the 2007-2011 period), a ratio well above low-income countries (14 to 15 percent), middle-income countries (13 percent), and high-income countries (6 to 9 percent). That is, in relative terms, as a region LAC has one of the highest ratios of electricity losses in the world (Exhibit 3).

The ranking remains unaltered when performed by region instead of by income categories; LAC loses about 3 percentage points more than Africa does, on average. However, it is important to emphasize the case of India where losses are above 22 percent, a level that given its size and annual consumption of electricity represents a significant amount of energy lost (see Exhibit 4) [6].

What is more, the ratio estimated for LAC (17 percent) does not include Haiti, a country that has experienced historic losses of more than 50 percent. Adding Haiti to the LAC average increases the region's loss ratio to 19 percent. In the case of LAC, these measures do not change significantly when compared against figures for the last year with available information (2012).

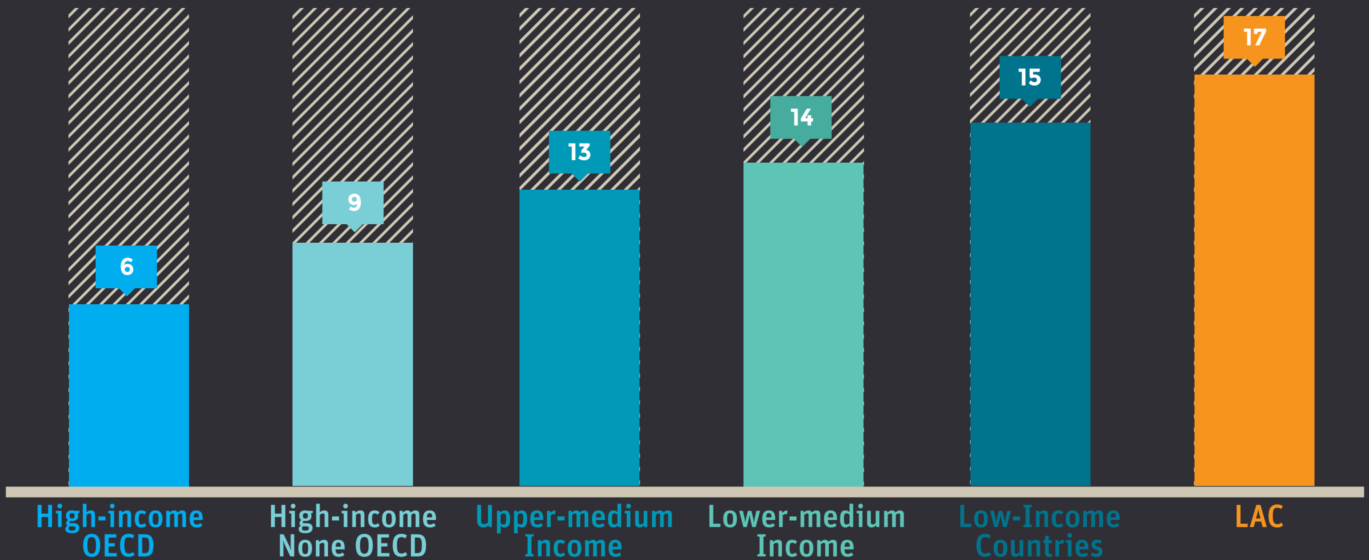
These figures include both technical and nontechnical and as explained previously, some degree of technical loss is inherent to the transport of power current. This issue shall be addressed in order to continue analyzing these ratios.

6 This country is classified as low-middle-income following the World Development Classification and as part of Asia and Oceania following the classification in EIA.

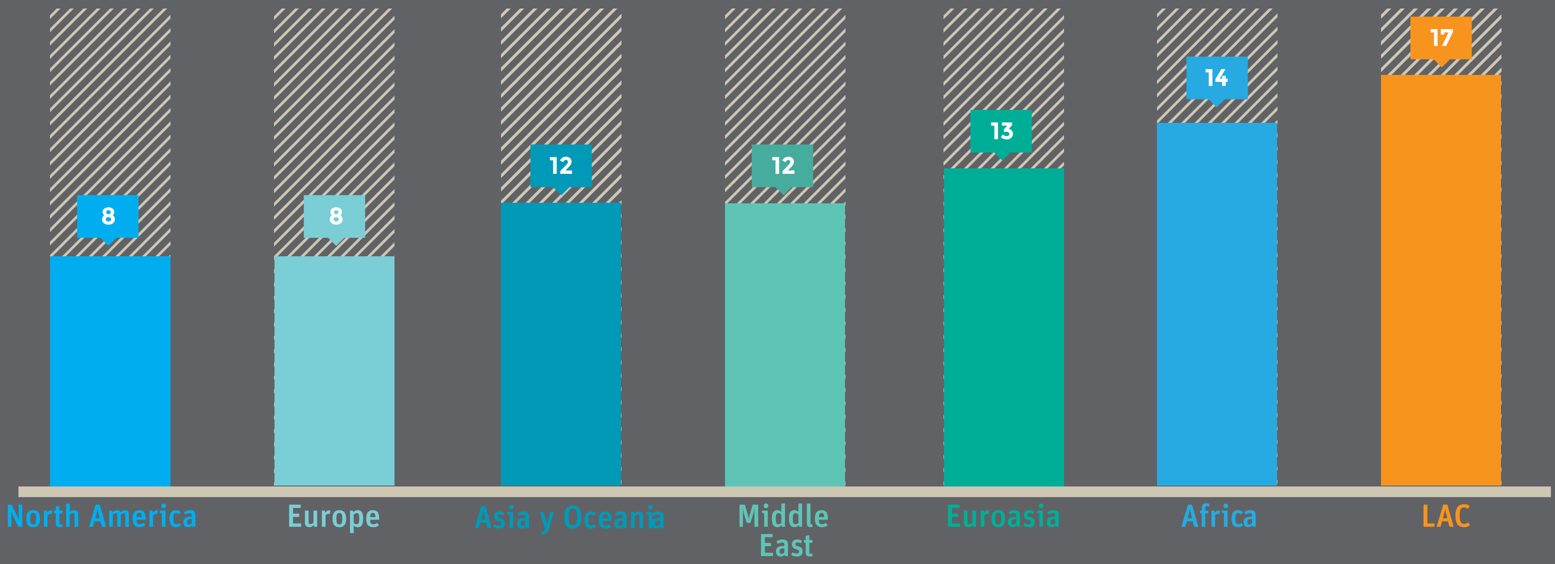
Exhibit 3

LAC's Loss Ratio is One of the Highest in the
(By percentage; five-year country average of the ratio of electricity losses to electricity output; includes losses in transmission and distribution)

By Income Level



By Region



Note: Average for the period 2007-2011. LAC does not include Haiti; including Haiti would increase its ratio to about 19%.
Source: Prepared by the authors based on data from regulators, utilities, ECLAC and the U.S. Energy Information Administration.

HOW MUCH ELECTRICITY DO THESE RATIOS REPRESENT

how much electricity is lost?

Before expressing these ratios in power units (terawatt hours—TWh), expected levels of electricity losses are discounted. That is, in order to obtain a figure of electricity losses due to inefficiencies and nontechnical causes, we should first discount a reference level of losses. This reference should be understood as an "acceptable" level; losses that surpass such level reveal inefficiencies that can and should be addressed. For purpose of calculating power units lost and its associated costs; this Brief sets this standard at 10 percent[7]. This represents a conservative cap, having into account benchmarks as high-income countries (with losses around 8 percent) or even countries with low level of losses in LAC region.

As shown in Exhibit 4, world electricity losses are around 290 TWh, which would be equivalent to the total electricity consumed by Mexico and Peru in 2013. LAC loses around 90 TWh per year, representing a third of the electricity losses in the world—a considerable amount. This figure is equivalent to two times the annual electricity consumption of Peru, or enough to cover the projected increase in electricity demand in Chile over the next 30 years.[8] The amount of power lost is greater than the electricity needed to satisfy the projected increases in electricity demand among the 30 million people who have no access to electricity in LAC today.[9]

These figures are aggregated estimates and consider annual averages over the 2007–2011 period. This is useful to avoid anomalous years with high levels of losses due to climatological events or peak oil prices. However, taking time-averages also smooth the estimate, reflecting information of past years instead of more recent situations. Indeed, in 2012, the year for which the most recent information is available, LAC registered 240 TWh of electricity losses, of which roughly 100 TWh are losses above 10 percent of total electricity output (compared to the 90 TWh average over 2007-2011).

These figures represent a considerable impact on the environment, given that greenhouse gases are emitted during power generation. Inefficiencies in the power systems logically require increased electricity generation to meet final consumption, which in turn results in increased greenhouse gas emissions. Although the energy mix in LAC is relatively clean, given the prominent role hydropower plays in power generation, this situation becomes relevant in countries where generation relies heavily on fossil fuels, as in Mexico, the Dominican Republic, Honduras, and Nicaragua.

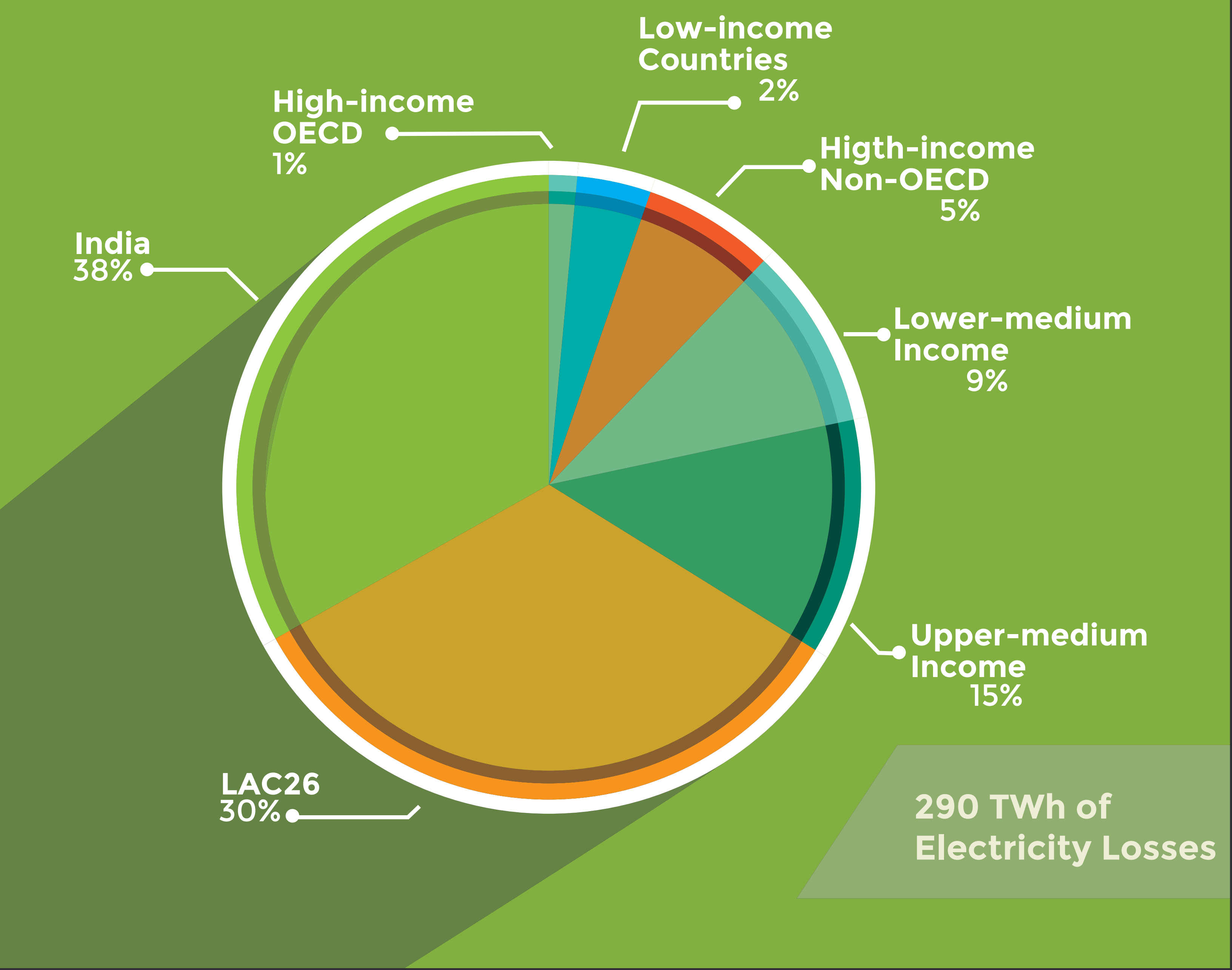
7 This reference ratio is based on the following considerations: (1) the average electricity ratio over the last 20 years in well-performing countries (assumed to be high-income) is, on average, between 6 and 9 percent (see Exhibit 3 and 5); (2) the Prospective of the Electricity Sector of Mexico sets a target level in 2018 of 8 percent (SENER, 2013); and (3) Estimations based on some rural areas of Colombia show technical electricity losses in those areas, under relatively efficient conditions, around 10 percent (PGGSGBP, 2010).

8 Based on a pool of forecasts detailed by BJES (forthcoming).

9 This assumes an annual consumption of 2,000 KW per person without access to electricity. Per capita consumption is estimated as the average per capita consumption in LAC countries (excluding Haiti) (Source: World Bank, World Development Indicators). The total number of households without electricity is extracted from the International Energy Agency for 2009.

Exhibit 4

Percentage Shares in Annual World Electricity Losses
(Discounting 10 percent of electricity output, based on an average of the years 2007-2011)



Source: Prepared by the authors based on data from regulators, utilities, ECLAC and the U.S. Energy Information Administration.

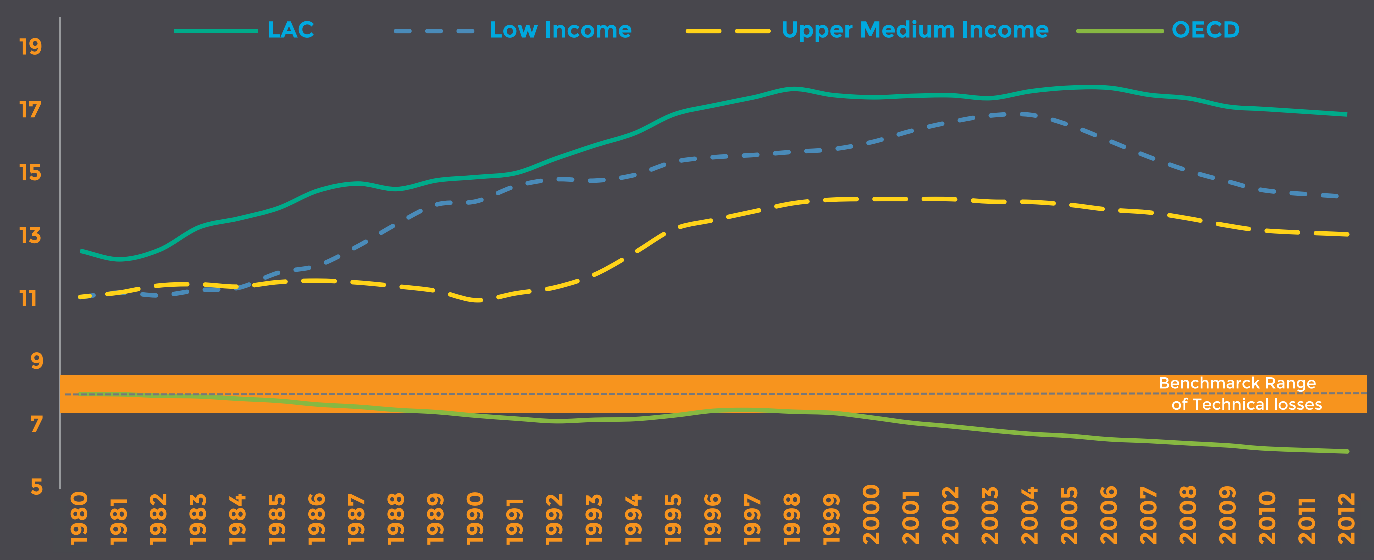
This situation is even more alarming when we observe the trend over the last three decades. Over that period, LAC did not show improvement in electricity loss ratios, but instead worsened. Exhibit 5 shows the rolling average electricity loss ratio of LAC countries compared to the OECD, middle-income, and low-income countries. Average electricity losses in the region showed a rising trend from around 13 percent in 1980 to 17 percent in 2012. In contrast, low-income and middle-income countries have shown a decrease over the last decade. OECD countries also show a downward trend from 8 percent in 1980 to 6 percent in 2010. In sum, the gap between LAC countries and high-income countries has expanded.

Further research is necessary to have a better understanding of all the factors that contribute to this overall trend. This lack of improvement may be related to insufficient investment in infrastructure to address the dynamic growth of Latin American cities over the last 30 years. On the other hand, the hardening of economic conditions in LAC during the 1980s and part of the 1990s could also have played a role in the increasing losses. Note that it is only after this period that electricity losses began to stagnate at around 17 percent.[10]

Exhibit 5

Trends in Electricity Losses by Income Level: No Significant Improvement for Latin America and the Caribbean

(Moving three-year average by percentage)



*Low-income includes low- and middle-low income countries.
Source: Prepared by the authors based on data from the U.S. Energy Information Administration.

10 For a review of the Latin American case see Elizalde and Jiménez (2013), more evidence of this relationship is found in Smith (2004) and Jamil (2013).

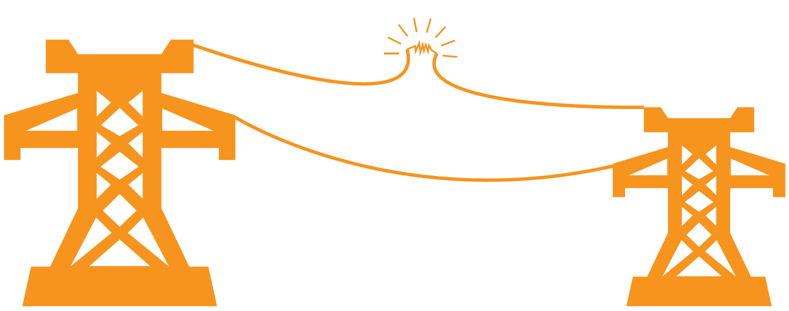
3 ELECTRICITY LOSSES BY COUNTRY IN LATIN AMERICA AND THE CARIBBEAN

Electricity Losses by Country in Latin America and the Caribbean

As shown in the previous section, there has been little variation in electricity losses in LAC as a region over the last decade. This section provides a more detailed view of intra-regional differences in electricity losses across 26 LAC countries. Overall, electricity losses are a widespread, severe problem in almost all LAC countries, representing an estimate financial cost for the electricity industry that ranged from US$11 to US$17 billion in 2012.

Exhibit 6 shows annual electricity losses as a percentage of total electricity output in 26 LAC countries. There is wide variation across countries, from 6 percent in Trinidad and Tobago to 56 percent in Haiti. According to this measure, only six of the 26 countries do not have a losses problem. The cut-off point for those six is Costa Rica, which has a loss ratio around 10 percent. The remaining 20 LAC countries exhibit losses above both the international reference of 8 percent and above our reference point of 10 percent. Moreover, approximately half of the 26 countries show losses equal to or above 17 percent of total electricity output.

These figures clearly suggest that measures to reduce electricity losses would have positive economic returns in LAC, particularly from the viewpoint of the utilities. However, this is not straightforward in all cases. Even when it is desirable to reduce electricity losses to zero, in fact, it is not always financially beneficial to implement further measures beyond a minimally efficient level of technical losses[11]. LAC is evidently nowhere near this minimal level (as can be the case of high income countries). Nonetheless, it raises the discussion about the desired efficiency levels in the power sector taking into account its environmental impacts. Environmental consideration could substantively affect the "acceptable" levels of electricity losses and how they are valuated. For example, environmental regulation is already being implemented requiring that more efficient power transformers be used in transmission and distribution networks for industrial applications[12].

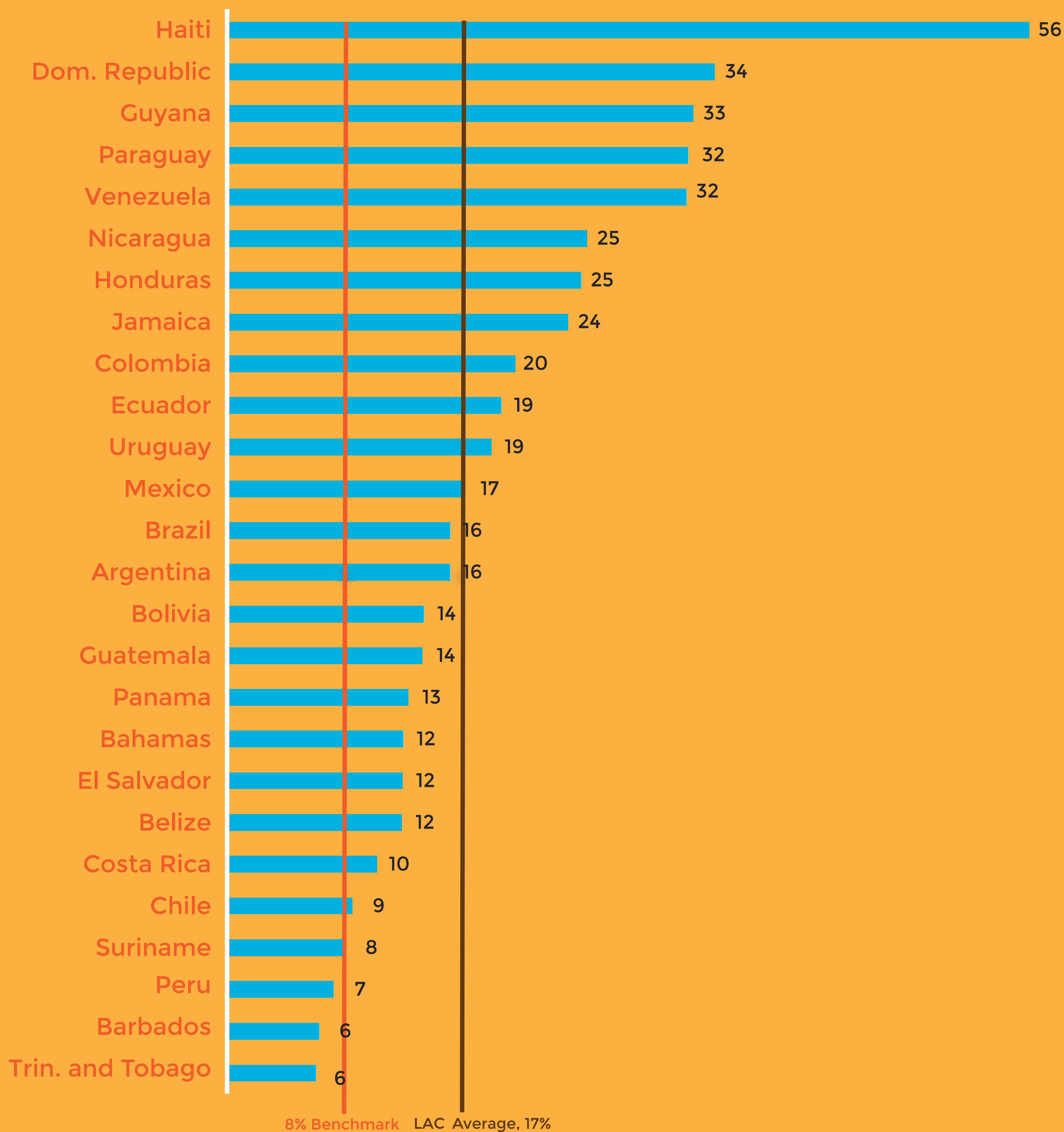


11 Within the sample included in this work, minimum levels for high-income countries are 3–5 percent of total electricity output.

12 See Directive EU 2009/125/EC related to Ecodesign and its regulation 548/2014

Exhibit 6

Electricity Losses in Latin American and Caribbean Countries
(As a percentage of total electricity output; average of last five years of available data)



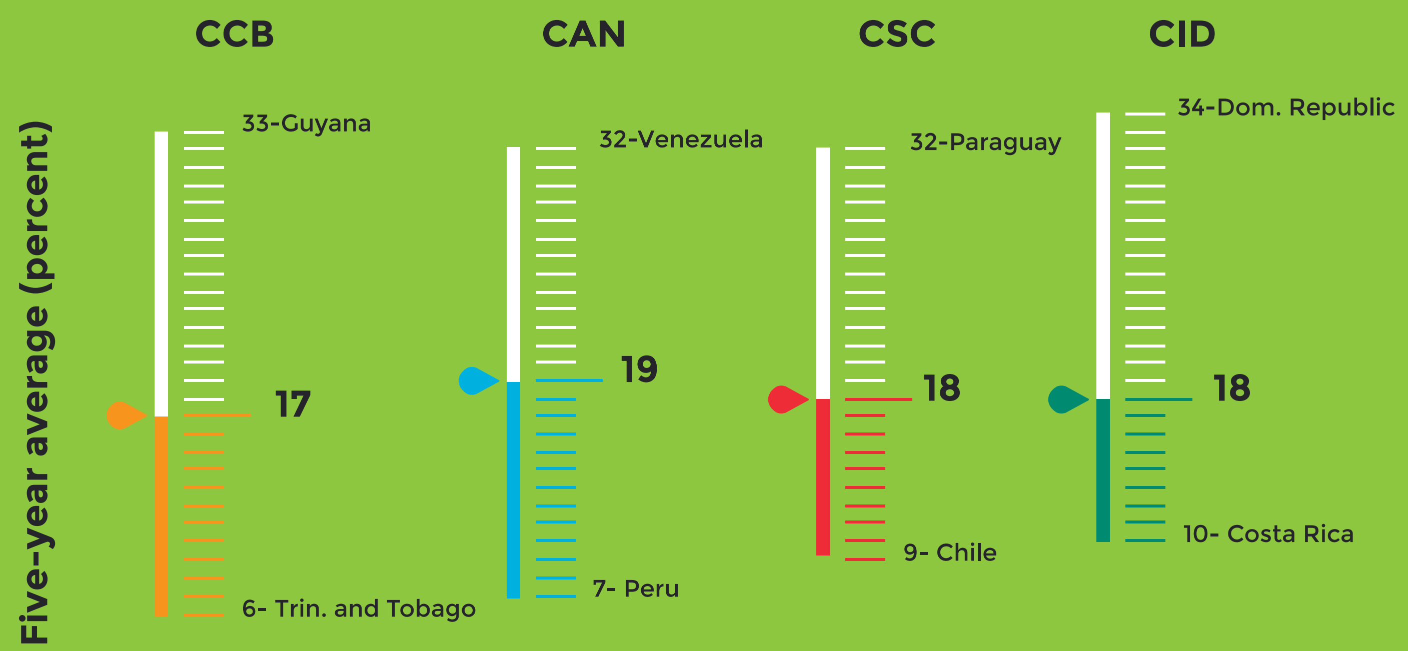
Note: The LAC average does not include Haiti.
Source: Prepared by the authors based on data from regulators, utilities, ECLAC, and the U.S. Energy Information Administration.

Losses of electricity are a significant problem in all sub-regions of LAC, with an average sub-regional loss ratio ranging from 17 to 19 percent. Exhibit 7 presents the most (and least) affected countries by group. Translating these ratios into power, and discounting 10 percent of electricity losses as before; Venezuela lost around 30 TWh, representing two-thirds of the net electricity generated from fossil fuels, showing one of the highest values for the Andean region. The Dominican Republic tops the list for Central American countries, with electricity losses being equal to half of the electricity produced with oil. Guyana and Paraguay register values above 30 percent, revealing equally startling rates for the Caribbean and Southern Cone regions.

Exhibit 7

Electricity Losses in Latin America and the Caribbean by Subregion

(As a percentage of total output; average of last five years available)



Note: Caribbean Countries (CCB), Southern Cone (CSC), Andean Countries (CAN), Central America, Mexico, Panama and Dominican Republic (CID). Average of CCB does not include Trinidad and Tobago. Haiti is not included.
Source: Prepared by the authors based on data from regulators, utilities, ECLAC, and the U.S. Energy Information Administration.

HOW HAVE THESE LOSSES ENVOLVED IN EACH COUNTRY?

Exhibit 8 presents electricity losses ratios from the last year of available information compared against their change over the last five years. Countries situated in the top-left quadrant of this Exhibit have reduced their losses, however, they still show high loss levels, suggesting that more aggressive measures are needed. Note that this is especially the case in countries that, despite efforts to combat the problem, still have loss levels above the LAC average of 17 percent.

In this context, recent efforts have been made to reduce losses in the Dominican Republic, where the IDB and other international financing agencies have committed approximately US$400 million to strengthen the national program to combat electricity losses. This program is mainly concentrated in urban areas with enhancements in transmission and distribution stations and networks. Over the last five years the country has reduced its losses by roughly 4 percentage points.

Similar efforts, with significant improvements over the period under review, have been undertaken in Ecuador and Nicaragua. In these countries loss ratios decreased by 4 and 5 percentage points, reaching 16 and 23 percent, respectively, by 2012.

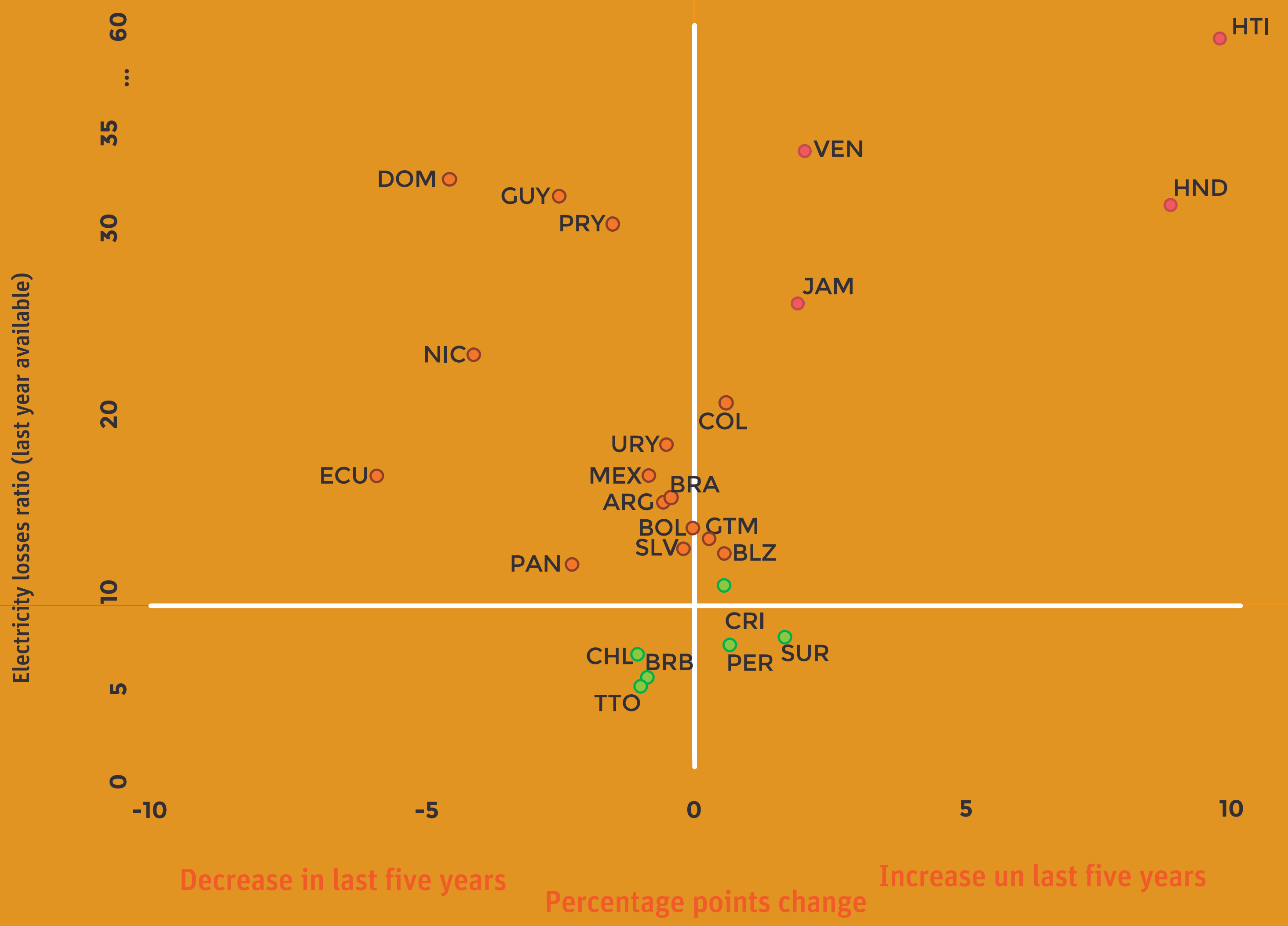
On the other hand, note that those countries floating near the LAC average of 17 percent have seen almost no change in recent years. This cluster includes a very heterogeneous[13] set of countries: Colombia, Uruguay, Mexico, Brazil, Argentina, Guatemala, Bolivia, El Salvador, and Belize, with loss ratios between 12 percent and 20 percent.

Finally, countries in the top-right quadrant of Exhibit 8 face the most difficult situation, with high levels of losses that have increased in recent years.

13 For example in terms of geography, electricity generation mix, private participation in the power sector and income levels, among other characteristics.

Exhibit 8

Recent Changes in Electricity Losses in Latin American and Caribbean Countries
(By percentage)



Note: This figure refers to the last year available (y-axis ~2012) and change over the last five years available (x-axis).
For most countries, data were available for the period between 2008 and 2012 or for even more recent five-year periods.
Two exceptions are The Bahamas, for which we only have data for 2010, and Venezuela, for which we have data for 2010, 2011 and 2012.
Source: Prepared by the authors based on data from regulators, utilities, ECLAC, and the U.S. Energy Information Administration.

Even in those countries where electricity losses are relatively low, there are utilities that have faced significant challenges due to the socioeconomic or geographic conditions of the areas they serve. For example, utilities serving rural areas with less population density in El Salvador and Peru have loss ratios that are markedly higher than their countries' averages. Still, electricity losses can also be concentrated in high-density areas, as is the case in Mexico and Uruguay.

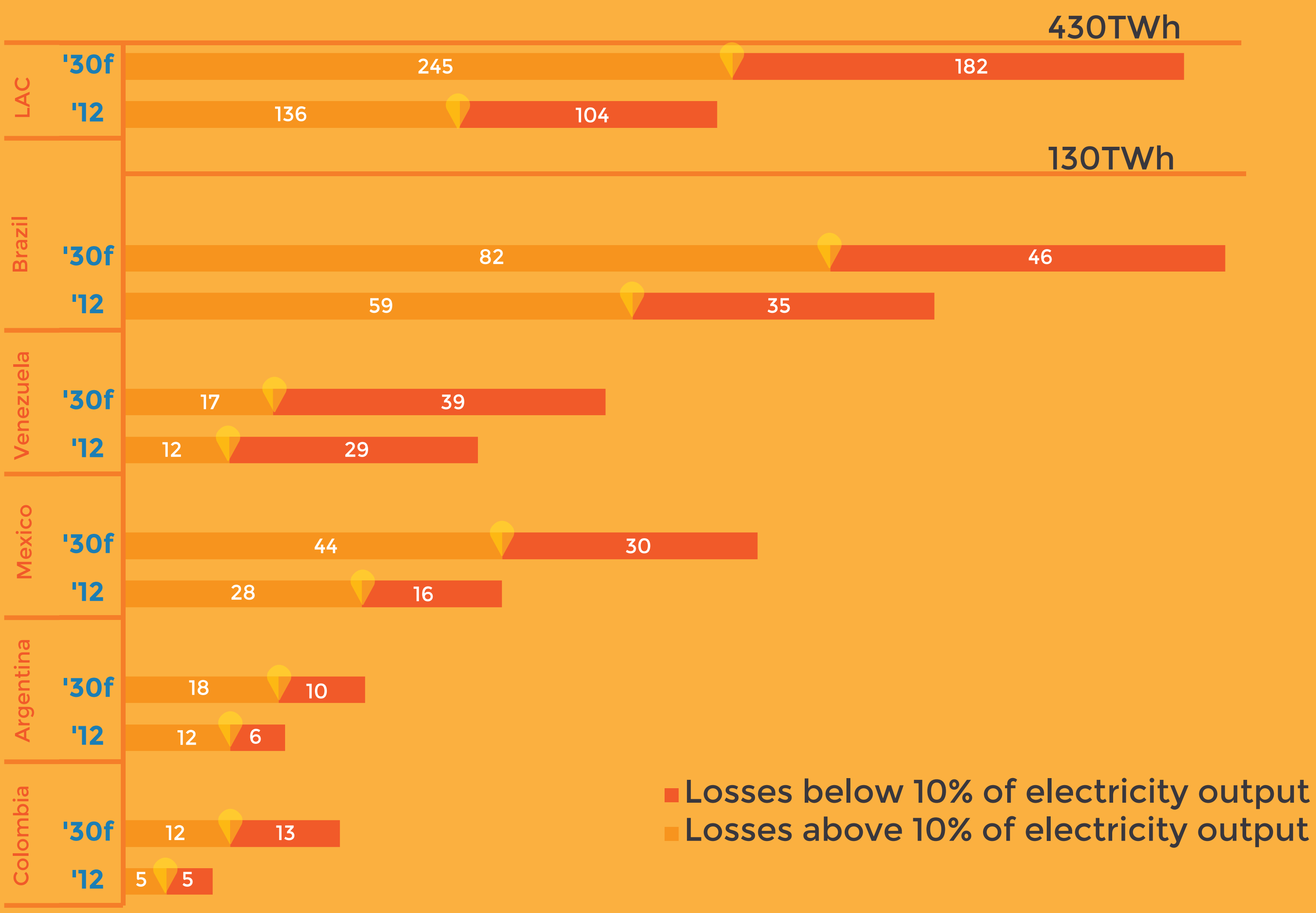
HOW MUCH ELECTRICITY WOULD BE LOST IN 2030?

Without improvements in the current situation, annual electricity losses in LAC would reach 427 TWh in 2030, of which around 182 TWh would be losses above 10 percent of total output. This is equivalent to two times the electricity generated by the largest hydroelectric power station in LAC, Paraguay‘s Itaipu.

Exhibit 9 presents projections of losses up to 2030, set against losses registered during 2012. The five countries included in the Exhibit represent 80 percent of electricity consumption and 90 percent of the total losses in TWh in LAC. If actual loss ratios were maintained, those countries could lose up to 310 TWh, of which 137 TWh would be losses above 10 percent of total electricity output (orange bar).

Exhibit 9

What if the Trajectory of Electricity Losses in LAC Remains Unchanged?
(Estimated loss ratios by percentage in 2030 compared to 2012)



Note: f indicates estimations for electricity losses in 2030 based on the forecast of electricity consumption of BEJS (forthcoming).
Losses in 2030 are calculated maintaining the same ratios of electricity losses as in the period 2007-2011.
Source: Prepared by the authors based on data from regulators, utilities, ECLAC, and the U.S. Energy Information Administration.

WHERE DO ELECTRICITY LOSSES OCCUR?

By subsector,[14] electricity losses are mainly concentrated in distribution, which accounts for up to 80 percent of total losses in a subsample of 15 countries that had available data. In general, transmission losses are relatively low, ranging from 1.6 percent in Bolivia to 3.7 percent in Honduras. The exception is Paraguay, where 8 percent of losses occur during transmission.

In the case of Paraguay, inefficiencies are mainly caused by overruns of transmission infrastructure connecting generation sources to consumption centers. Besides, rising demand over the last years has increased the severity of overloads during peak hours and seasons exacerbating existing flaws in its transmission system. In partnership with other sources of international financing, the IDB is supporting the Multiphase Power Transmission Program to upgrade Paraguay's transmission lines and substations, including the installation of the first 500 kV power line in the country.

As shown in Exhibit 10, most of the electricity is lost in the distribution system, potentially due to nontechnical factors. This implies that intervention oriented to reduce electricity losses would have redistribution effects between end-users and utilities.

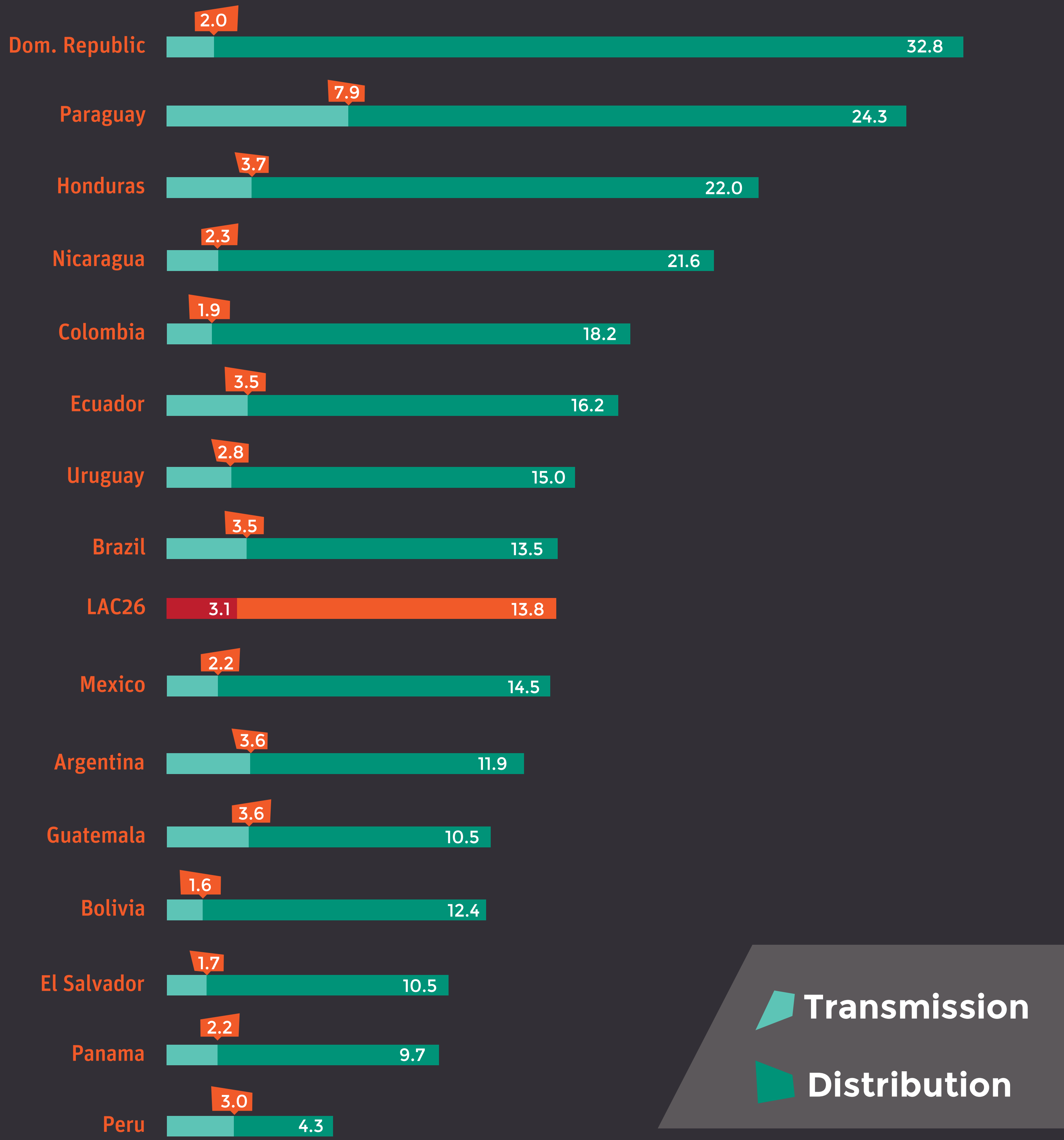
In contrast, technical losses in distribution are mainly concentrated in rural areas, and to this extend, they represent a challenge to utilities and electricity access policies, which look for providing services to areas with low population density.

14 Caution is required when comparing subsectors across countries, since their definitions can vary widely. For example, in Peru, Argentina and Ecuador, transmission includes only those power lines above 130 kV. In Brazil and Mexico, the transmission subsector includes only those power lines above 230 and 160 kV, respectively. In contrast, in Bolivia, Paraguay, and Nicaragua, transmission also include lines of 60 - 69 kV.

Exhibit 10

Losses Are Mainly Concentrated in Distribution

(By percent; average over the last five years available)



*The estimate for Brazil is based on a sample of utilities in distribution. Source: Prepared by the authors based on data from regulators and utilities.

OVERALL, WHAT IS THE FINANCIAL COST OF LAC'S ELECTRICITY LOSSES?

The costs of electricity losses are sensitive to the prices at which they are valuated. Rough estimates suggest that electricity losses in LAC ranged from about US$11 to US$17 billion in 2012, equivalent to 0.19 percent to 0.3 percent of the region's GDP. Exhibit 11 scales those magnitudes as a percentage of GDP in each country, showing that the cost of losses ranges between a minimum of 0.02 percent (Argentina) and a maximum of 2.3 percent (Dominican Republic). These figures broadly quantify the amount of income that utilities fail to collect for services delivered. They also represent a significant opportunity cost for those resources: the annual financial loss is comparable to the expenditures of the biggest social programs in the region. In Brazil, the minimum estimated cost of electricity losses represents 0.26 percent of GDP, equivalent to one-third of the budget allocated to Bolsa Familia. Similarly, electricity losses in Mexico represent between 0.12 and 0.3 percent of its GDP, comparable to the budget of Oportunidades (which represents around 0.5 percent of its GDP).

This situation threatens the financial sustainability of electric utilities, reducing their financial capacity to undertake investments and improve the overall infrastructure of the system. Moreover, this lost income indirectly affects progress toward the target of universal access to modern energy services, as public companies (which to some extent continue to be the mechanism responsible for the extension of distribution networks and rural electrification) have fewer resources to improve access to electricity in rural areas. It is important to remember the 31 million people who still lack access to electricity in LAC; 3 million of them are in Mexico, 6 million in the eight countries of the Central American Integration System, and 4 million in Haiti.[15] In all of these countries, electricity losses continue to represent a significant roadblock to inclusive growth and a barrier to achieving the goals of "Sustainable Energy for All" (SE4ALL).

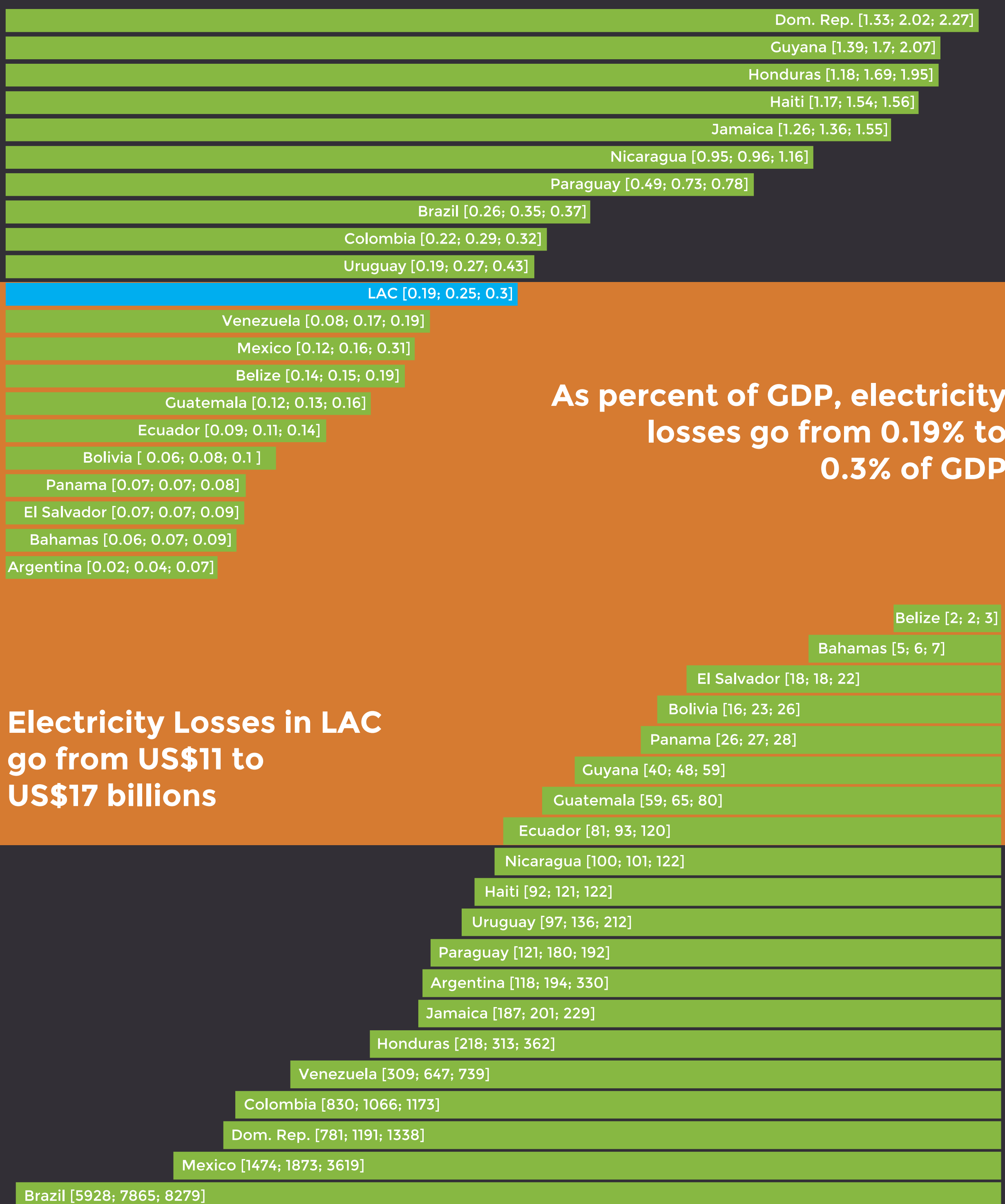
Taking into account different periods, cut-offs and valuations, the ranges estimated in this Brief include calculations reported by some utilities and other agencies. For example, in Uruguay, it is estimated that nontechnical losses represented approximately US$80 million in 2010[16]. In Honduras, ECLAC estimates that reducing losses (including technical and nontechnical) to a level of 12 percent would represent additional annual revenues of US$135 million—enough resources to cover investment needs in distribution, transmission, and generation, including also investments to reach the targets of universal access to electricity[15].

15 These references were kindly provided by the Energy and Natural Resources Unit at ECLAC. In their estimation for Honduras, electricity losses were valued at US$10 per MWh. In contrast, the valuations presented here take the 2012 average Residential, Industrial, and Commercial prices of US$ 14.5, US$20.7, and US$23.9 per MWh, respectively.
16 See UTE (2010).

Exhibit 11

Cost of Electricity Losses in Latin American and Caribbean Countries

(in 2012, only electricity losses above 10 percent of total output were considered for these estimates)



Note: [Min, Median, Max] as valuated at minimum, median and maximum between electricity prices of the residential, commercial and industrial sector. The figures are in logarithmic scale, ranked by the median cost. Only electricity losses above 10 percent of total output were considered for these estimates. All calculations were based on the last year of available data ~2012.

Source: Prepared by the authors based on data from regulators, utilities, ECLAC, and the U.S. Energy Information Administration.

For these calculations, a range of values was assigned to electricity losses based on residential, industrial, and commercial electricity prices in each country. The minimum, median, and maximum prices for each country were used to estimate the costs between brackets reported in Exhibit 11. These values are derived from the total gigawatt hours (GWh) lost above the 10 percent of total output. This is an oversimplification, but it still allows for an estimate of the extent of financial losses that result from electricity losses occurring mainly in distribution. More accurate valuations should be based on country-specific loss factors and should differentiate between technical and nontechnical losses in each phase of the electricity chain. Alternative methods to place a value on electricity losses include the following:

- Loss values could be based on the costs of generation and transportation of electricity, i.e., they could be valuated at the marginal costs of generation and transportation, taking into account the technology used for generation.

- Losses could be valued using prices on electricity exchange markets. An advantage of this approach is that such prices could be interpreted as an economic market valuation that better reflects demand and the preferences of the agents.

- As was done in this Brief, the cost of losses could be based on retail prices. Depending on the type of loss, the pricing could also take into account the supplier‘s margins. In the case of technical losses in distribution, the pricing could be based on the net of the supplier‘s margins.

Further considerations in costing electricity should take into account that:

- The cost of losses can change significantly with the timing of peaks and loads, which are usually associated with relevant changes in generation costs. In particular, the cost of electricity losses is relatively higher in those countries that rely more heavily on fossil fuels for generation.

- Besides the cost of generation, losses impose costs on power lines to the extent that they contribute to overall capacity requirements.

- Environmental costs are usually not internalized in electricity prices or in the cost of generation. As previously mentioned, these costs are mainly related to CO_2 emissions in the generation process, and accounting for such environmental costs would provide an economic and social value for this problem.

4 Final Remarks

This Brief has described the scope of the electricity losses in Latin America and the Caribbean, quantifying the severity of this problem in 26 countries. The estimates show that LAC presents average losses of 17 percent per year, one of the highest ratios in the world, and place about half of the region's countries above this average. After allowing for a conservative level of technical losses, this ratio translates into 100 TWh lost in 2012, representing a financial cost ranging from US$11 billion to US$17 billion. Without substantial reductions in this ratio—as has been the case over the last three decades—losses could go up to 182 TWh in 2030.

It is emphasized that electricity losses have an important impact on both the supply and demand side. On the supply side, a reduction in technical losses implies gains in the efficiency of the electricity system, helping to reduce the amount of electricity production required to meet demand, with significant associated environmental benefits. On the demand side, nontechnical losses are synonymous with unpaid consumption, potentially fostering overconsumption of electricity and potentially putting a heavy burden on electricity supply capacity. From a business approach, a reduction of power losses would also lead to increased financial sustainability for the utilities, mainly resulting from increased billing and cost reductions associated with a better match between capacity investment and demand.

Beyond the efficiency argument, policies aimed at reducing commercial losses should include an assessment of the distributional impact of those policies. Particular attention should be given to the welfare impact of loss-reduction interventions on low-income end-users—that is, demand-side subsidies with adequate targeted properties could accompany those interventions to guarantee adequate levels of service affordability. A reduction in nontechnical losses would represent a reallocation of revenue and benefits between a group of end-users and utilities that provide electricity services. The net balance would depend on the causes of nontechnical losses and on the characteristics of the consumers.

Further Research

What can be done to reduce electricity losses? In line with the strategy and policies of the IDB Infrastructure Department (IDB, 2013, 2014), this Brief is an effort to contribute to the monitoring and analysis of electricity losses in LAC. Possible next steps include building on the experiences and efforts of LAC countries, in order to identify best practices, opportunities for improvement, and areas where special efforts should be made. In this context, some topics to be addressed call for a number of follow-up studies, including:

- Understanding the main drivers and consequences of electricity losses, monitoring them on a comparable basis, and clearly differentiating between technical and nontechnical losses.

- Studying the experiences of countries and utilities in dealing with electricity losses, taking into account such dimensions as regulatory pricing of electricity, the governance of utilities, investment needs, and the net cost-benefit balance of measures to reduce electricity losses. Case studies would represent a valuable source of information to evaluate the performance of specific measures and innovations such as smart grids, smart meters and distributed generation.

- Conduct a comprehensive cost-benefit analysis that goes beyond analyzing the direct effects of losses to address associated externalities, including environmental effects and long-term performance impact on variables such as grid expansion, electricity prices, and investments.

- Identify the materiality of each cause of electricity losses, both technical and nontechnical. Nontechnical losses seem to respond to economic conditions external to the power system. This issue must be taken into account when dealing with nontechnical losses among low-income groups of customers and/or in the presence of external economic shocks. Social tariffs or transitory subsidies can be considered in order to avoid placing undue financial burdens on the utility.

To the best of our knowledge, behavioral aspects have not been addressed even though such evidence represents a critical factor in the design of policies and interventions. In particular, no empirical literature has focused on causal links between drivers and effects of electricity losses. These questions are mainly related to nontechnical losses, including: (i) Do high electricity prices increase the probability of electricity theft?; (ii) How does under-metered electricity affect consumption patterns?, and (iii) Do better quality services decrease the probability of theft and/or fraud?

References

Balza, L., R. Jiménez, R. Espinasa, and T. Serebrisky. F (BJES). Forthcoming. "How Much Energy for LAC? Sweet Dreams and Bitter Realities." Inter-American Development Bank.

Balza, L., R. Jiménez, and J. Mercado (BJM). 2013. "Privatization, Institutional Reform, and Performance in the Latin American Electricity Sector". IDB Technical Note TN-599. Inter-American Development Bank, Washington, DC.

Bentancur, D., F. Bianco, F. Boions, and M. Rey (BBBR). 2010. Beneficios por reducción de pérdidas eléctricas en la red de Distribución al adoptarse niveles de tensión superiores en la media tensión. Revista CIER No. 56. Comisión de Integración Energética Regional, Montevideo.

Colegio de Ingenieros Civiles de México (CICM). 2011. Estudio de integración de proyectos de Infraestructura, Tomo I, México.

Economic Commission on Latin America and the Caribbean (ECLAC). 2010, 2011, 2012. Centro América: Estadísticas del Sub-Sector Eléctrico. Natural Resources and Energy Unit, ECLAC, Santiago.

Elizalde, A., and R. Jiménez. 2013. Key Drivers of Electricity Losses in Power Systems: Experiences and Lessons in Latin America. Paper presented at the 22nd World Energy Congress.

Inter-American Development Bank (IDB). 2013. Public Utilities Policy. Inter-American Development Bank, Washington, DC.

Inter-American Development Bank (IDB). 2014. Sustainable Infrastructure for Competitiveness and Inclusive Growth. IDB Infrastructure Strategy. Inter-American Development Bank, Washington, DC.

International Energy Agency (IEA). 2012. World Energy Outlook. Paris: International Energy Agency.

Jamil, F. 2013. On the Electricity Shortage, Price and Electricity Theft Nexus. Energy Policy 54: 267–72.

Office of Gas and Electricity Markets (Ofgem). 2003. Electricity Distribution Losses. A Consultation Document.

Office of Gas and Electricity Markets (Ofgem). 2009. Electricity Distribution System Losses. Non-Technical Overview. Paper prepared for Ofgem by Sohn Associates Limited. Available at https://www.ofgem.gov.uk/publications-and-updates/electricity-distribution-systems-losses-non-technical-overview.

Pinzón, I., M. Garzón, G. Guerrero, M. Salgado, D. Salgado, M. González, J. Bedoya, and O. Piñeros (PGGSGBP). 2010. Metodología para el cálculo de pérdidas técnicas en circuitos radiales con alta dispersión de clientes en áreas rurales. Revista CIER No. 55. Comisión de Integración Energética Regional, Montevideo.

SENER. 2013. Prospectiva del Sector Eléctrico 2013-2017. Secretariat of Energy, Mexico.

Smith, T. 2004. Electricity Theft: A Comparative Analysis. Energy Policy 32(18): 2067–076.

World Bank. 2009. Reducing Technical and Non-Technical Losses in the Power. Sector Background Paper for the World Bank Group Energy Sector Strategy. World Bank, Washington, DC.

Administración Nacional de Usinas y Trasmisiones Eléctricas (UTE). 2010. Hurto de Energía Eléctrica en Uruguay.