www.adelat.com

NO INVESTMENT, NO TRANSITION

THE FUTURE OF POWER DISTRIBUTION IN LATIN AMERICA

AUTHORS AND COLLABORATORS

Grupo Mercados Energéticos (GME), David Felipe Acosta, Viviana Vitto, Aldo Pessanha, Alessandra Genu Dutra Amaral, María Antonieta Borrero, Roberto Cajamarca Gómez, Alejandro Falkner Falgueras, Sandra Marcela Quijano López, Horacio Nadra, Luiz Felipe Falcone De Souza, Claudio Bulacio, Ernesto San Miguel, Hilario Vistolet, María José Perez Vanmorlegan, Patricio Molina, Gastón Blanquet, Clarissa Machado, Talita Darwiche, Mariana Silva Barreto, Francisco Mualim, Victor Tavera, Pablo Jofré, Mónica Cataldo, Gina Pastrana, Sergio Zambrano, Dimas Carranza, Jorge Ponce, Julio Luján.

01

INTRODUCTION AND OBJECTIVES

The energy transition has become a global imperative driven by the urgent need to mitigate the effects of climate change, ensure energy security, and promote sustainable development. In Latin America, this transition is not only an opportunity to reduce greenhouse gas emissions and meet international climate change commitments, but it also represents a path toward the modernization of economies and the improvement of the quality of life of its population. In this context, the power distribution segment plays a crucial role. Power distribution, as the final link in the energy supply chain, is responsible for delivering electricity from transmission grids to end-users, and its role has become even more relevant in a scenario where renewable energy integration, the electrification of new uses, and digitalization are emerging trends. However, the transition to a cleaner and more efficient energy system cannot be achieved without significant investment in electric distribution infrastructure.

The primary objective of this study is to offer a detailed overview of the investment needs in the power distribution segment of seven key countries in Latin America: Argentina, Brazil, Chile, Colombia, Ecuador, Guatemala, and Peru. This analysis focuses on the implementation of eleven key vectors associated with energy transition, which include from the electrification of new uses to the universalization of electric service.

The investment model was commissioned by the Latin American Energy Distributors Association (ADELAT) and developed by the consultancy Grupo Mercados Energéticos, taking the "Connecting the Dots" study conducted by Deloitte for Eurelectric as a reference and adapting it to the Latin American context.

The study is built around two prospective scenarios for 2040: a theoretical scenario of "effective transition," which aims to reach electrification levels similar to those proposed by the study conducted for the European Union by 2030, and a scenario of "partial transition" adjusted to the region's particularities and limitations. These scenarios were fed with data provided by distribution companies associated with ADELAT, a detailed characterization of the current situation in each country, and power demand projections.

The study aims to contribute to a common language that allows different actors in the electric sector—including regulators, distribution companies, governments, and civil society— to understand and effectively communicate the key elements of distribution activities in the context of the energy transition, promoting more coordinated action around it.

Additionally, the benefits are qualitatively explored from operational, economic, social, and environmental perspectives. This comprehensive approach allows investments to be understood not only as a necessary cost but also as an opportunity to generate value in multiple dimensions, contributing to the sustainable development of the region.

The success of the planned investments in the energy transition largely depends on the existence of key enablers that allow for their effective implementation. These enablers include, among others, an adequate regulatory framework, access to financing, and investments in other segments of the electric chain. The study analyzes these enablers, highlighting public policies and regulatory schemes that can incentivize the necessary investments. It also addresses the importance of international cooperation, and public-private partnerships as key mechanisms for mobilizing the required resources.

This document is organized into eight chapters. Following this introduction, the new role of power distribution in the energy transition is presented, followed by a detailed analysis of the investments needed to support eleven key transition vectors. The study's methodology, investment model results, enablers for investments, a characterization of the associated benefits, and conclusions and recommendations complete the structure of the study.

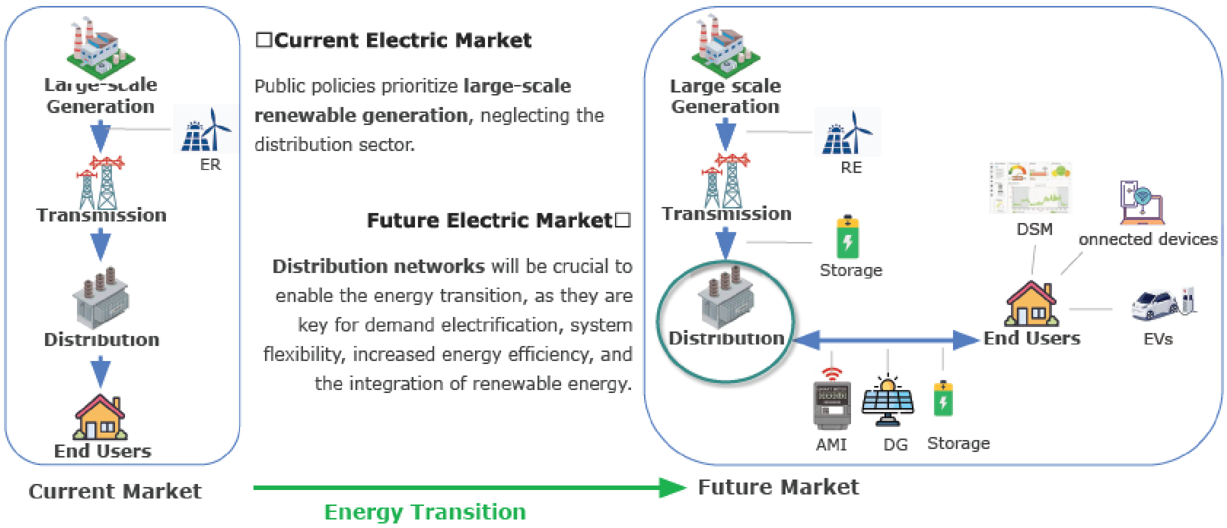
02

THE NEW ROLE OF POWER DISTRIBUTION IN THE ENERGY TRANSITION

Historically, the focus of planning and investment in the power sector has been on generation and transmission, with distribution networks considered the last link in the electricity supply chain. However, the energy transition is reversing this dynamic. The increasing penetration of distributed generation, the demand for electrification of sectors such as transportation and heating, and the need for greater resilience in the face of extreme weather events have placed power distribution at center stage.

The decentralization of energy generation, driven by the proliferation of distributed generation (DG) technologies, requires a reconfiguration of distribution networks. Networks that were once essentially unidirectional, designed to carry electricity from large generation plants to final consumers, must now handle bidirectional energy flows, managing both the injection of locally generated energy and consumer demand. This shift toward a more distributed and dynamic network transforms the role of Distribution System Operators (DSOs) from mere electricity transporters to active managers of a complex infrastructure that connects heterogeneous generation and consumption resources. DSOs are responsible for balancing supply and demand in real time and ensuring the stability and resilience of the electric system.

Figure 1. The New Role of DSO in the Energy Transition



The effective integration of distributed generation depends largely on the digitalization and automation of distribution networks. Technologies such as Advanced Distribution Management Systems (ADMS), smart metering, and remote control devices are essential for monitoring and managing the inherent variability of renewable sources. Additionally, the ability to predict and respond to fluctuations in generation and demand in real time becomes a critical component in maintaining system stability and avoiding grid congestion or failures.

For example, advanced metering systems allow for granular monitoring of power consumption, providing valuable data that can be used to optimize network operation and improve service quality. Likewise, distribution automation systems can identify and isolate faults automatically, minimizing the impact on users and enhancing grid resilience.

The electrification process of sectors traditionally dependent on fossil fuels, such as transportation and industry, is creating significant new demand for distribution networks. Electric mobility, in particular, is emerging as a key factor in the energy transition with a direct impact on distribution infrastructure. The charging of electric vehicles not only increases the total demand for electricity but also introduces new consumption patterns that must be carefully managed to avoid overloads and ensure system stability. Additionally, the possibility of electric vehicles acting as distributed energy resources with the capability to inject energy back into the grid (Vehicle-to-Grid, V2G) adds an additional layer of complexity and opportunity for distribution network operators.

Climate change is increasing the frequency and intensity of extreme weather events, posing a growing threat to power distribution infrastructure. The resilience of grids, i.e., their ability to withstand and quickly recover from these events, has become a central concern in the planning and operation of distribution networks. Modernizing infrastructure, along with implementing risk management strategies, is crucial to ensuring a reliable and continuous electricity supply in an environment of increasing climatic uncertainty. DSOs must invest in more robust and flexible infrastructure, including the implementation of underground networks, advanced protection systems, and the adoption of risk management strategies. Furthermore, the integration of energy storage at the distribution level can offer greater operational flexibility, allowing the grid to maintain supply even during generation or transmission outages.

Service quality is another aspect that takes on new importance in the context of the energy transition. Users not only demand a reliable electricity supply but also services that adapt to their needs in terms of flexibility, sustainability, and cost. DSOs must ensure that as the grid becomes more complex, the quality of service is maintained or even improved, which will require investments in infrastructure modernization and monitoring and control technologies.

The success of the energy transition and the adaptation of distribution networks to their new role depends largely on the regulatory framework and policies implemented in each country. It is essential that regulators and policymakers develop an environment that promotes investment in infrastructure modernization, the adoption of advanced technologies, and the integration of new energy sources. This includes creating remuneration schemes that incentivize innovation and efficiency, as well as implementing policies that ensure equity in access to the benefits of the energy transition..

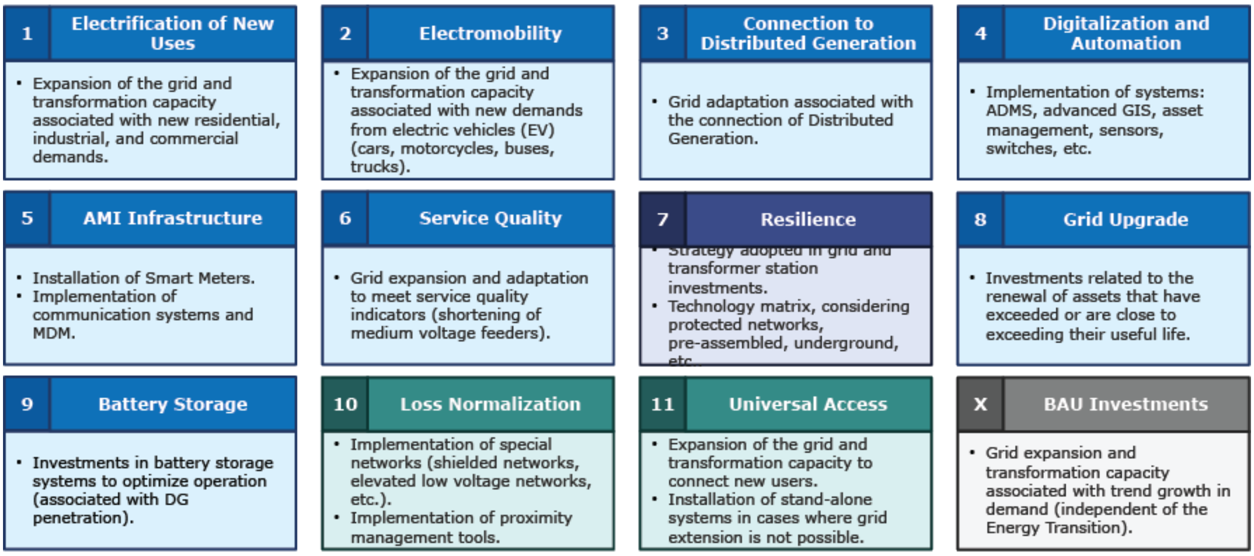
In conclusion, the new role of power distribution in the energy transition not only redefines how infrastructure is designed and operated but also presents new challenges and opportunities for sector stakeholders. The ability of distribution networks to adapt and evolve in this new environment will be decisive for the success of the energy transition in Latin America. Investing in the modernization of distribution networks, digitalization and automation, resilience and service quality is not an option but a necessity to ensure a sustainable and prosperous energy future for the region.

03

INVESTMENTS ASSOCIATED WITH ENERGY TRANSITION

The comprehensive transformation of power distribution infrastructure for the energy transition involves a series of strategic investments aimed at modernizing the networks, making them more resilient, efficient, and capable of supporting the growing demand for electric energy from new uses, electromobility, distributed generation, and digitalization. Below are eleven key investment vectors that are additional to the business-as-usual (BAU) growth, which serves as a reference to compare progress under the Effective and Partial Transition scenarios.

Figure 2. Investment Vectors in Energy Transition



ELECTRIFICATION OF NEW USES

Electrification of new uses is one of the fundamental pillars of the energy transition. It refers to the process of replacing fossil fuel consumption with electricity in sectors that have historically relied on these fuels, such as industry, transportation, heating, and cooking. In Latin America, this process is crucial to reducing greenhouse gas emissions, improving energy efficiency, and decreasing dependence on imported fuels.

The investments required in distribution systems in this area include expanding transformation capacity and distribution networks to meet new residential, commercial, and industrial demands. This implies the construction of new substations, the installation of higher-capacity transformers, and the extension of medium- and low-voltage lines. In addition, advanced

> “Investments are distributed with a special focus on those that have the greatest impact on modernization.

technologies will need to be implemented to enable more efficient energy management.

The main challenge is to ensure that the electric infrastructure can manage these new consumption patterns without compromising the stability and quality of service. This requires not only investments in physical assets but also in staff training and the adoption of new technologies that allow for more flexible and resilient network operations.

ELECTRIC MOBILITY

Electric mobility is one of the most important vectors of the energy transition. The adoption of electric vehicles (EVs) is gaining momentum worldwide, and Latin America will be no exception. However, the mass deployment of these vehicles presents significant challenges for power distribution networks, which must adapt to manage the additional load and the new demand patterns they generate.

Investments in distribution systems in this area focus on increasing network and transformer capacity to meet EV demand. Additionally, it is crucial to develop charging infrastructure in both urban and rural areas. This ranges from fast charging stations on highways and service stations to residential and commercial chargers.

The distribution grid must be capable of supporting the simultaneous operation of multiple EV charging stations without causing overloads or service interruptions. To do this, investments are needed in demand management systems and smart charging technologies that optimize grid usage and minimize associated costs.

Moreover, integrating EVs into the distribution network opens up new opportunities, such as the Vehicle-to-Grid (V2G) concept, where electric vehicles can return energy to the grid during times of high demand. This requires investments in communication and control technologies as well as modernizing the grid to enable bidirectional energy flows.

DISTRIBUTED GENERATION CONNECTION

DG is an essential component of the energy transition as it allows the integration of renewable sources directly into the distribution grid. In Latin America, solar photovoltaic energy, in particular, has experienced significant growth, with a growing number of households, businesses, and industries installing solar panels for self-consumption.

To facilitate the integration of DG, distribution networks must be adapted through investments in grid retrofitting and the incorporation of specialized DG equipment. This includes the installation of inverters, monitoring and control systems, and protection devices that can manage the variability of renewable generation without compromising grid stability.

A key aspect of DG is the management of bidirectional energy flows. Distribution networks, which have traditionally been unidirectional, must now manage energy injection from multiple points, requiring greater flexibility and responsiveness. Investments in control and automation technology are essential to enable the grid to respond dynamically to changes in generation and demand.

DIGITALIZATION AND AUTOMATION

Digitalization and automation are the cornerstones of the distribution grid of the future. These technologies allow network operators to manage an increasingly complex infrastructure more efficiently and flexibly. Investments in this area include the implementation of Advanced Distribution Management Systems (ADMS), advanced Geographic Information Systems (GIS), commercial and asset management systems, and the installation of sensors, automatic switches, and other devices that enable real-time monitoring and control of the grid.

ADMS, in particular, is a critical technology that enables the optimized operation of the distribution network by integrating information from various sources and facilitating real-time decision-making. This includes the ability to automatically detect and isolate faults, manage energy demand, and optimize the use of available resources.

In addition, digitalization facilitates the implementation of innovative solutions, such as demand response, where consumers can adjust their consumption based on price signals or the availability of renewable energy, contributing to balancing supply and demand in the grid.

Automation, on the other hand, allows for more efficient and safer grid operation, reducing the need for manual intervention and improving resilience to unexpected events. This ranges from the automation of substations and distribution lines to the implementation of self-healing technologies that allow the network to quickly and efficiently restore service in the event of failures.

ADVANCED METERING

Advanced Metering Infrastructure (AMI) is a fundamental part of the modernization of distribution networks in the context of the energy transition. AMI systems include smart meters, communication systems, and Meter Data Management (MDM) systems that enable accurate real-time monitoring of electricity consumption at all levels of the grid.

Investments in AMI allow network operators to obtain detailed data on energy consumption, which is essential for efficiently managing the grid in an increasingly complex and dynamic environment. These data can be used to optimize network operation, improve billing accuracy, and provide consumers with detailed information on their consumption, which can encourage more rational energy use.

Additionally, AMI systems are a key component for the implementation of dynamic tariffs that reflect variations in energy generation costs and promote more efficient and sustainable consumption. They are also essential for integrating distributed generation and electric mobility, as they allow for the management of energy injection into the grid and the optimization of charging infrastructure.

SERVICE QUALITY

Service quality in power distribution is a crucial aspect that directly influences user satisfaction and the reliability of the energy supply. In the context of the energy transition, improving service quality becomes even more important due to the increasing dependence on electricity for new uses, electric mobility, and distributed generation.

Investments in this area focus on expanding and upgrading the network to meet more demanding service quality indicators. This includes reducing the duration and frequency of interruptions, as well as improving the voltage quality supplied to users. Achieving this requires implementing advanced technologies that enable real-time monitoring and control of the grid, such as sensors and advanced management systems.

A key aspect is shortening medium-voltage (MV) feeders, which reduces exposure to failures and improves the ability to respond to unforeseen events. The implementation of automatic restoration equipment and the creation of alternative energy routes are also essential investments to improve service quality.

RESILIENCE

The resilience of the electric distribution network is its ability to withstand, adapt, and quickly recover from adverse events such as natural disasters, technical failures, or cyberattacks. In the context of the energy transition, improving the resilience of the grid is critical to ensuring a continuous and reliable energy supply, especially in the face of increasingly unpredictable and extreme weather conditions.

Investments in resilience include adopting strategies and technologies that enable the grid to better handle these challenges. This includes implementing networks protected against wildfires and other natural threats, as well as deploying preassembled technologies and underground networks, which are less vulnerable to external damage. Furthermore, investing in the modernization of control centers and telecommunications (CCTT) is crucial to improve the network's response capability during emergencies.

An integral approach to resilience also considers diversifying generation sources, including distributed generation and energy storage, which allows the grid to operate autonomously in case of disconnection from the main grid.

GRID MODERNIZATION

The modernization of the electric distribution grid is a continuous task that involves the renewal of assets that have exceeded or are nearing the end of their useful life. This modernization is essential to maintaining the reliability of the electric supply and adapting the grid to the new demands emerging from the energy transition.

Investments in this area focus on replacing transformers, cables, substations, and other critical components that no longer meet current efficiency and safety standards. Additionally, grid modernization includes incorporating more advanced technologies that allow for more flexible and efficient operation, such as the automation of substations and the digitalization of monitoring and control processes. A key aspect of grid modernization is the integration of capacities to handle distributed generation and electric mobility, which requires careful planning and significant investment in new technologies and personnel training.

For the purposes of this study, this vector is composed of all those modernization investments that are additional to those already included in the business-as-usual growth vector and are required to achieve the effective and partial energy transition scenarios.

BATTERY STORAGE

Energy storage through batteries is a technology that plays a crucial role in the energy transition as it allows for optimizing grid operation and improving the integration of renewable sources such as solar and wind energy. Batteries provide an effective solution for managing the variability of renewable generation and ensuring a continuous electricity supply during periods of high demand or grid outages.

Investments in battery storage systems focus on installing large-scale batteries at strategic points in the distribution grid. These batteries can be used to store energy during low-demand periods and release it when demand is high, helping to balance supply and demand and reduce the need to activate costly and polluting thermal power plants.

Moreover, energy storage is essential for integrating distributed generation and electric mobility, as it allows for better management of energy flows in the grid and ensures that locally generated energy can be used efficiently. Batteries also play a crucial role in improving grid resilience, as they can provide backup power in case of supply interruptions.

LOSS REDUCTION

Reducing losses in the power distribution grid is a significant challenge in Latin America, where both technical and non-technical losses represent a considerable percentage of the distributed energy. Reducing these losses is essential to improving the grid's operational efficiency, lowering costs for consumers, and minimizing environmental impact.

Investments in this area include the implementation of special networks, such as shielded networks and low-voltage grids with better efficiency standards. These networks are designed to reduce technical losses associated with cable resistance and inefficient connections.

In addition, it is crucial to invest in advanced metering technologies, such as AMI systems, which allow for precise monitoring of energy consumption and the detection of non-technical losses, such as energy theft or fraud. The implementation of data analysis tools is also essential for identifying loss patterns and taking corrective actions.

Reducing losses not only improves grid efficiency but also contributes to energy equity by ensuring that all users pay for the energy they consume and lowering rates for those who already comply with regulations.

UNIVERSALIZATION

Universalizing access to electricity is a key objective in most Latin American countries, where rural and remote communities still lack access to a reliable and affordable electricity supply. The energy transition offers an opportunity to accelerate the electrification process using innovative technologies and business models that can bring electricity to the most challenging areas to reach.

Investments in universalization include extending the distribution grid to rural and hard-to-reach areas, as well as installing distributed generation systems, such as solar panels and microgrids, which can provide an autonomous and reliable electricity supply in isolated communities.

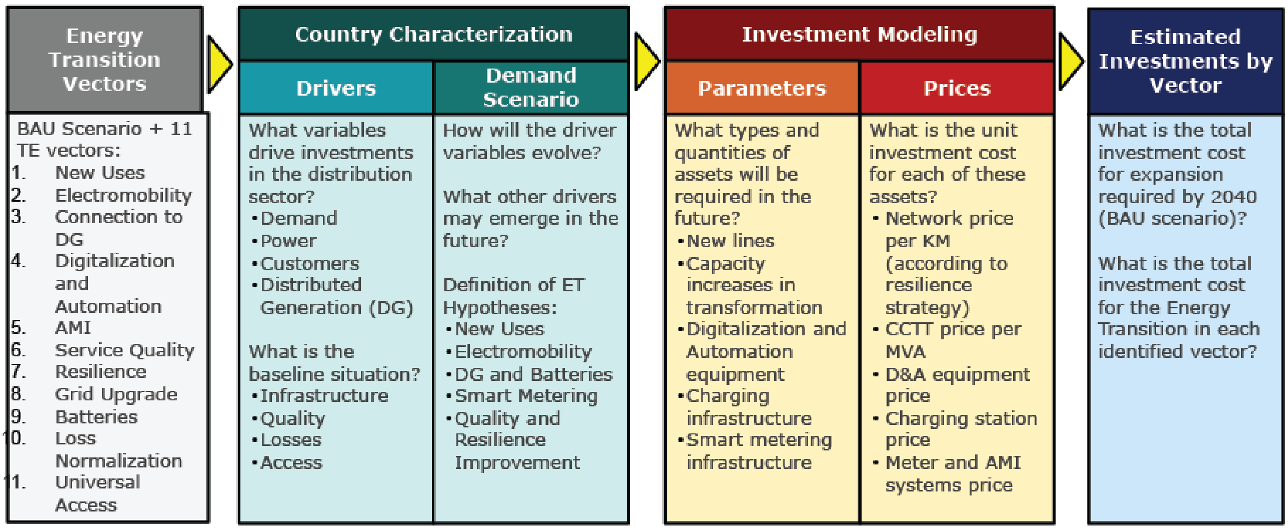
Universalizing access to electricity not only improves people's quality of life but also drives economic and social development by allowing communities to participate in the modern economy and access basic services such as education, healthcare, and communication.

04

METHODOLOGY

The estimation of investment needs in the power distribution segment was carried out using a model that contemplates different energy transition scenarios. These scenarios aim to illustrate two possible pathways that Latin American countries could follow in their journey towards a comprehensive modernization of the electric sector. This chapter describes the methodological approach adopted to characterize the current situation of the distribution systems, national energy policy goals, demand projections, technical parameters and asset costs, as well as the definition of the energy transition scenarios that guide the analysis.

Figure 3. Investment Model Structure



CHARACTERIZATION OF THE BASELINE SITUATION

The first step in the study's methodology was to characterize the baseline situation of power distribution systems in the selected countries: Argentina, Brazil, Chile, Colombia, Ecuador, Guatemala, and Peru. This characterization was carried out through the collection and analysis of data provided by distribution companies associated with ADELAT, complemented with information from secondary sources.

The characterization included an assessment of the existing infrastructure, identifying installed capacity, asset conditions, grids coverage, and levels of technical and non-technical losses. Additionally, service quality indicators, such as the duration and frequency of interruptions, were analyzed. This phase also involved a review of current operational practices.

Key drivers were considered, such as the evolution of electricity consumption, installed capacity, and the need for new capacities to support growing demand, the number and types of customers, and the current and potential impact of Distributed Generation (DG) on the ditribution network. Additional variables such as service quality, technical and non-technical losses, and access to electricity were also included. The table below summarizes the main indicators of the baseline characterization for each analyzed country.

Table 1. Baseline Situation by Country

Item	Unit	Argentina	Brazil	Chile	Colombia	Ecuador	Guatemala	Peru
Demand and Baseline Infrastructure								
Peak Demand	GWh	140,883	582,234	77,314	79,985	30,188	12,548	53,992
Number of Clients	MW	29,105	101,472	11,549	11,413	4,641	1,970	7,606
Average Network Density	Millions	15.6	92.2	8.0	16.6	5.7	3.9	8.6
Network Length	m/client	29.7	45.3	24.9	35.6	40.3	29.4	35.7
MV Network Share (Total Network MV + LV)	KM	463,308	4,172,761	199,880	590,681	228,198	114,682	307,133
LV Network Share (Total Network LV + MV)	%	52.5%	26.3%	50.2%	49.8%	48.9%	59.8%	57.0%
Peak Demand	%	47.5%	73.7%	49.8%	50.2%	51.1%	40.2%	43.0%
Electromobility								
Electric Fleet	%	0.01%	0.08%	0.13%	0.12%	0.05%	0.02%	0.01%
Connection to DG								
Installed Capacity Prosumer	MW	30	25,818	203	211	70	83	5
Installed Capacity Utility Scale	MW	0	0	2,691	0	0	125	0
Distributed Generation (DG) Share	%	0.04%	6.86%	6.11%	0.36%	0.31%	2.57%	0.01%
AMI Infraestructure								
Smart Meter Deployment	%	1.00%	0.52%	8.85%	3.92%	3.12%	8.42%	1.31%
Service Quality								
Interruption Frequency Indicator (SAIFI/FMIK/FEC)	#	10.2	5.2	7.4	15.4	5.1	5.1	5.2
Duration Indicator (SAIDI/TTIK/DEC)	#	16.5	10.5	13.6	23.4	6.1	23.4	15.9
Battery Storage								
Installed Storage Capacity	MW	Not significant						
Normalization (Losses)								
Distribution Losses Level	%	15.6%	13.7%	10.2%	13.9%	15.0%	9.9%	9.8%
Universal Access								
Coverage Level	%	100.0%	99.5%	99.6%	95.5%	97.3%	89.9%	94.1%

The information collected made it possible to establish a clear baseline from which investment needs were projected, considering both current limitations and opportunities to improve system efficiency.

NATIONAL ENERGY POLICY GOALS

The analysis of national energy policy goals is fundamental to understanding the context in which the energy transition will take place in each country. These goals, established by national governments and regulatory bodies, define long-term objectives in terms of decarbonization, electrification, renewable energy integration, and service quality improvement.

The study considered policies and national plans such as emission reduction commitments under the Paris Agreement, rural electrification objectives, energy efficiency targets, and incentive programs for electric mobility and distributed generation. Specific regulations affecting the electric distribution sector, such as tariff frameworks, service quality requirements, and technical standards, were also taken into account.

Below is a summary of the main goals and projections for the countries considered in this study, based on current commitments and each nation's strategic plans.

“

The comprehensive transformation of the electricity distribution infrastructure for the energy transition involves a series of investments.

Table 2. National Energy Policy Goals and Projections

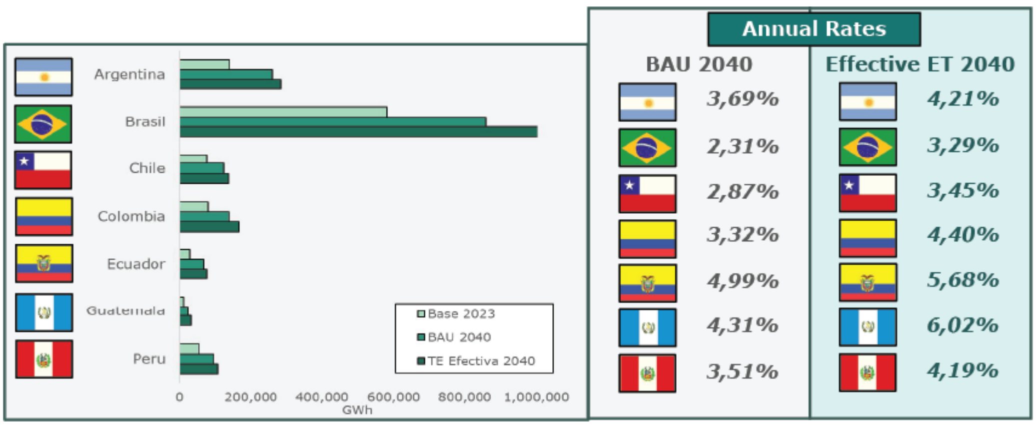
Goals and Projections							
Greenhouse Gas Emissions Reduction (NDC)	2030 Target: -27.7% IC, -37.5% C	2030 Targets: -37% IC, 2030: -43%	2030 Target: -30% IC, -35/45% C	2030 Target: -51%	2030 Target: -20/25% IC, -37.5% C	2030 Target: -11.2% IC, -22.6% C	2030 Target: -30% IC, -40% C
Renewable Generation	57% ER (w/ Hydro)	45% ER (Hydro)	80% ER (w/ Hydro)	Increase of 20 GW ER (w/ Hydro)	85% ER (Hydro)	64% ERNC	45% ERNC
Distributed Generation	1 GW Installed Capacity	37 GW Installed Capacity	6 GW Installed Capacity	X	X	X	5% Energy as DG (by 2040)
Electric Mobility (EV Fleet)	Cars 1%, Buses 20%, Trucks	Cars 8.5%, Buses 8.5%	Electric Vehicle Sales (by 2035)	EV 100 mil	EV 100 mil	X	Cars 171 mil, Buses 6.7 mil
Universal Access	100% by 2026	100%, no date specified	75% by 2024	100% by 2035	100% by 2030	100% by 2023	100% by 2028
Smart Metering	X	100%, no date specified	75% by 2025	X	X	100% by 2024	100% by 2024

DEMAND PROJECTIONS

Power demand projections are an essential component of the investment model as they determine the magnitude and type of infrastructure that will need to be developed. To create these projections, econometric models were used that incorporate macroeconomic, demographic, and technological variables, and hypotheses about the evolution of demand were defined, considering factors such as the electrification of new uses, demand growth associated with the adoption of electric vehicles, the impact of distributed generation and energy storage on grid demand, the effect of implementing advanced metering infrastructure (AMI), and additional demand derived from improving service quality and grid resilience.

This study presents demand projections corresponding to Business-As-Usual (BAU) Growth and the Effective Energy Transition (TE Efectiva) scenario, with a time horizon until the year 2040. Variations are recorded between countries due to differences in economic growth and demographic structure, with Ecuador and Guatemala showing particularly accelerated growth, and Brazil and Chile recording the lowest rates.

Figure 4. Energy Demand Projections



TECHNICAL PARAMETERS AND ASSET COSTS

To determine technical parameters and asset costs, consultations were held with companies associated to ADELAT, and technical and economic studies on power distribution technologies were reviewed.

Technical parameters were established for each of the energy transition vectors identified, including among others, the requirements for the expansion of new lines and transformation capacity to support increased demand and the integration of distributed generation, the investment needs in technology for grid digitalization, including ADMS systems, sensors, and remote control devices, the costs associated with the installation of charging stations and the implementation of smart meters and data management systems.

Similarly, unit costs of the assets needed to implement investments were estimated based on market prices and historical data. Costs per kilometer of grid, per megawatt of transformation capacity, and per unit of Distribution and Automation (D&A) and AMI equipment, among others, were included.

BUSINESS-AS-USUAL GROWTH SCENARIO (BAU)

The model considers a baseline scenario of business-as-usual growth for DSO (Business-As-Usual, BAU), which serves as a reference to compare the impact of investments in energy transition scenarios, estimating the evolution of electricity consumption until the year 2040 using an econometric projection approach. This approach is based on Ordinary Least Squares (OLS) models that use Gross Domestic Product (GDP) as the main explanatory variable for the growth in energy demand, assuming that the distribution grid continues to develop according to historical trends without significant changes in energy policy, technology adoption, or additional measures for the energy transition. The projection is made disaggregated by sectors, including residential, commercial, industrial, and others, considering investments according to two main categories:

Mandatory Investments: These include the investments that DSOs need to make to meet growing demand and network expansion to connect new users, complying with current regulations and addressing situations that could compromise operational safety, service quality, or the environment. In some cases, these investments may respond to regulatory requirements not directly related to electric operations but are mandatory by law, such as environmental impact corrections.

Discretionary Investments: These investments are planned and carried out based on internal company criteria, focusing on improving operational efficiency and maintaining competitiveness in the market. Discretionary investments can include technological upgrades, service expansion, or asset renewal to optimize operations and reduce costs.

ENERGY TRANSITION SCENARIOS

Energy transition scenarios consider a more ambitious evolution of the energy system driven by policies and technologies that seek to reduce greenhouse gas emissions and increase energy efficiency. These scenarios were designed to capture the different pathways that countries could follow in their journey toward a more modern, efficient, and resilient electric distribution grid.

Effective Transition: This scenario represents an approach where countries make a significant effort to achieve a robust and ambitious implementation of the necessary measures to modernize their power distribution networks. Under Effective ET, it is assumed that public policies, regulation, and energy sector stakeholders collaborate effectively to facilitate the required investments, resulting in the seven countries reaching electrification levels similar to those proposed by the “Connecting the Dots” study for the European Union by 2030, and much higher than the national policy goals and projections presented in section 4.2, particularly in distributed generation connection and electric mobility. The scenario also assumes universal access and 100% smart meter deployment by 2040, consistent with national goals, although with different target years.

In this scenario, there is a rapid and massive adoption of advanced technologies such as grid digitalization and automation, the integration of electric vehicles (EVs), and distributed generation (DG) connection. This scenario also includes additional growth in energy demand derived from the electrification of sectors that currently depend on conventional energy sources (such as LPG, diesel, and other fossil fuels.

In this scenario, the peak demand is projected using typical load profiles for each sector and solar generation curves. These profiles are crucial for understanding how variations in distributed generation and storage will impact demand at different times of the day and year. The projection is based on data from GME and tools like the GlobalSolarAtlas, developed by Solargis, ESMAP, and the World Bank.

Partial Transition: In this scenario, the progress toward grid modernization is more gradual, with slower adoption of advanced technologies and a focus on maintaining the basic operability of the grid. This scenario assumes that significant barriers, such as financial constraints, regulatory uncertainty, or lower political priority, limit countries' ability to make large-scale investments.

In this scenario, DG connection and EV penetration also reach levels higher than the national policy goals and projections, although the differences are more moderate, while the same assumption of universal access and 100% smart meter deployment by 2040 remains. The scenario envisions slower adoption of advanced technologies and more moderate electrification of new uses.

Below is a summary of the assumptions considered for each of the evaluated energy transition scenarios.

Table 3. Energy Transition Scenarios: Effective and Partial

Vector	Effective ET Scenario	Partial ET Scenario
Electrification of New Uses	Residential: Electrification of LPG and biomass. Industrial: Partial electrification (coal, biomass, gas, diesel, and fuel oil). Commercial & Public Sector: 100% electrified	Limited electrification scenario (50% of the Effective ET scenario)
Electromobility	Penetration of 20% of vehicle fleet	Penetration of 10% of vehicle fleet
Connection to DG	Distributed generation equivalent to 20% of total energy consumption	Distributed generation equivalent to 10% of total energy consumption
Digitalization and Automation	Fully digital and automated distribution. Implementation of ADMS, GIS, advanced systems, demand-side management, sensors, etc.	50% digitalization and automation. Implementation of SCADA and basic systems (GIS, etc.)
AMI	Full deployment of smart meters	Partial deployment of smart meters
Service Quality	Based on the characteristics of each country's grid. Decrease in frequency and duration of interruptions by -10%. Specific quality indicators like SAIDI/SAIFI (TTIK/FEC)	Based on the characteristics of each country's grid. Decrease by -5% in SAIDI/SAIFI (TTIK/FEC) indicators
Resilience	Active resilience regulation (90% Underground)	Active resilience regulation (10% Underground)
Battery Storage	Deployment of BESS as a backup for DG and storage at the system threshold	No deployment of BESS
Normalized Losses	Normalization of 100% of irregular customers	Normalization of 100% of irregular customers
Electrification of New Uses	Residential: Electrification of LPG and biomass. Industrial: Partial electrification (coal, biomass, gas, diesel, and fuel oil). Commercial & Public Sector: 100% electrified	Limited electrification scenario (50% of the Effective ET scenario)
Universal Access	Access to 100% guaranteed, with no space for stand-alone	Access to 100% guaranteed, with no space for stand-alone

To develop these scenarios, a flexible and standardized model was used to estimate the investment needs in the electricity distribution segment for each of the eleven identified investment vectors. The assessment of investment needs was carried out for each country, considering a time horizon up to the year 2040. The analysis is based on constant USD prices as of December 2023, providing an estimation of real values that facilitates comparison between different countries and scenarios.

It is important to highlight that the estimated investment amount for each scenario corresponds exclusively to those investments that would be carried out by the DSOs, excluding other investments that may be developed by different actors, such as those related to Distributed Generation connection assets or electric vehicle charging infrastructure.

Additionally, the resulting investments are not considered to be constrained by the regulatory, financial, or operational contexts of each country. These are necessary investments, regardless of current barriers, underscoring the importance of a policy and regulatory framework that facilitates their implementation.

05

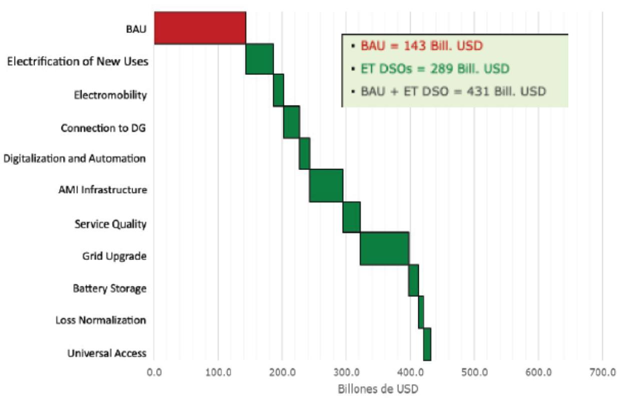
RESULTS OF THE INVESTMENT MODEL

This chapter presents the detailed results of the investment model for the energy transition in the power distribution segment across the seven countries considered. The results are analyzed under two scenarios: Effective Transition and Partial Transition. In both cases, the total required investment amounts are calculated, the vectors with the highest percentage weight are identified, and the average annual investments required per country are presented. Additionally, key indicators such as annual investments relative to GDP, per customer, and per MWh are analyzed.

EFFECTIVE TRANSITION SCENARIO

For the seven countries considered, the model estimates a total of USD 431 billion in cumulative investments required by 2040 by the Distribution System Operators (DSOs), excluding those in distributed generation connection assets (DG) that could be made by other agents. **This amount is 201% higher than the investments that would be made in the business-as-usual (BAU) growth scenario (USD 143 billion).**

Graph 1. Effective Transition Scenario Results (7 Countries Total)



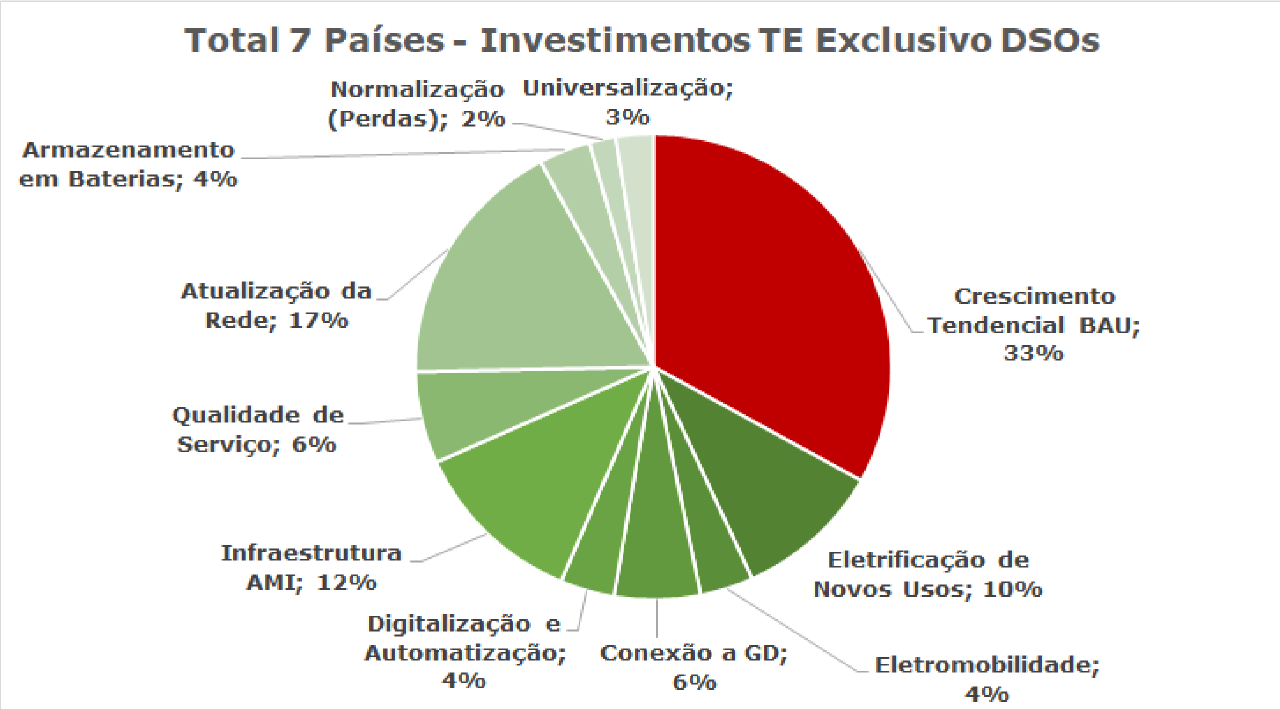
The annualized investments would represent between 0.19% and 0.50% of the GDP of the evaluated countries and between USD 75.4 and USD 97.4 per customer (based on the total number of connected customers). Finally, the projected investments per distributed energy are between USD 6.0 and USD 16.1 per MWh. Below is a summary of the estimated average annual investments for each country in the Effective Transition scenario.

Table 4. Average Annual Investments in the Effective Transition Scenario

Effective ET Investments by 2040: 11 Vectors + BAU (USD Billions/Year)							
Item	**Argentina**	**Brazil**	**Chile**	**Colombia**	**Ecuador**	**Guatemala**	**Peru**
BAU	0.8	5.6	0.2	0.9	0.4	0.2	0.3
11 ET Vectors	1.6	10.7	0.7	2.1	0.7	0.5	0.8

The investments are distributed across different vectors of the energy transition, with a particular focus on those that have the greatest impact on grid modernization and efficiency. The vectors with the highest percentage weight in this scenario are the BAU Growth vector, representing 33% of total investment. Regarding the energy transition, the vectors with the greatest weight are Grid Modernization (17%), AMI Infrastructure (12%), and Electrification of New Uses (10%).

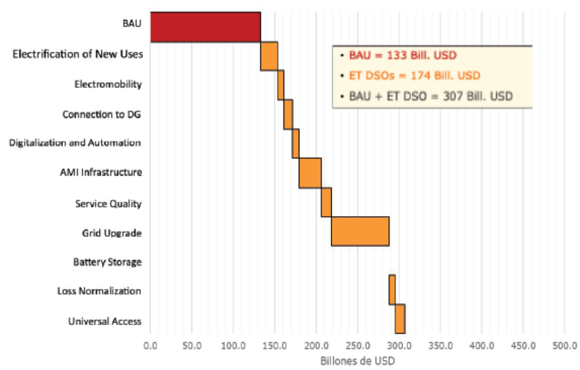
Graph 2. Distribution of Investment Vectors in the Effective Transition Scenario (7 Countries Total)



PARTIAL TRANSITION SCENARIO

In the Partial Transition scenario, the required investments are lower compared to the Effective Transition scenario, reflecting a slower adoption of advanced technologies and less integration of renewable energies and electrification of new uses. **The model estimates a total of USD 307 billion in cumulative investments required by 2040 for the seven countries considered,** which corresponds to the DSOs and excludes those in distributed generation connection (DG) assets made by other agents. **This amount is 131% higher than the investments that would be made in the business-as-usual (BAU) growth scenario (USD 143 billion).**

Graph 3. Partial Transition Scenario Results (7 Countries Total)



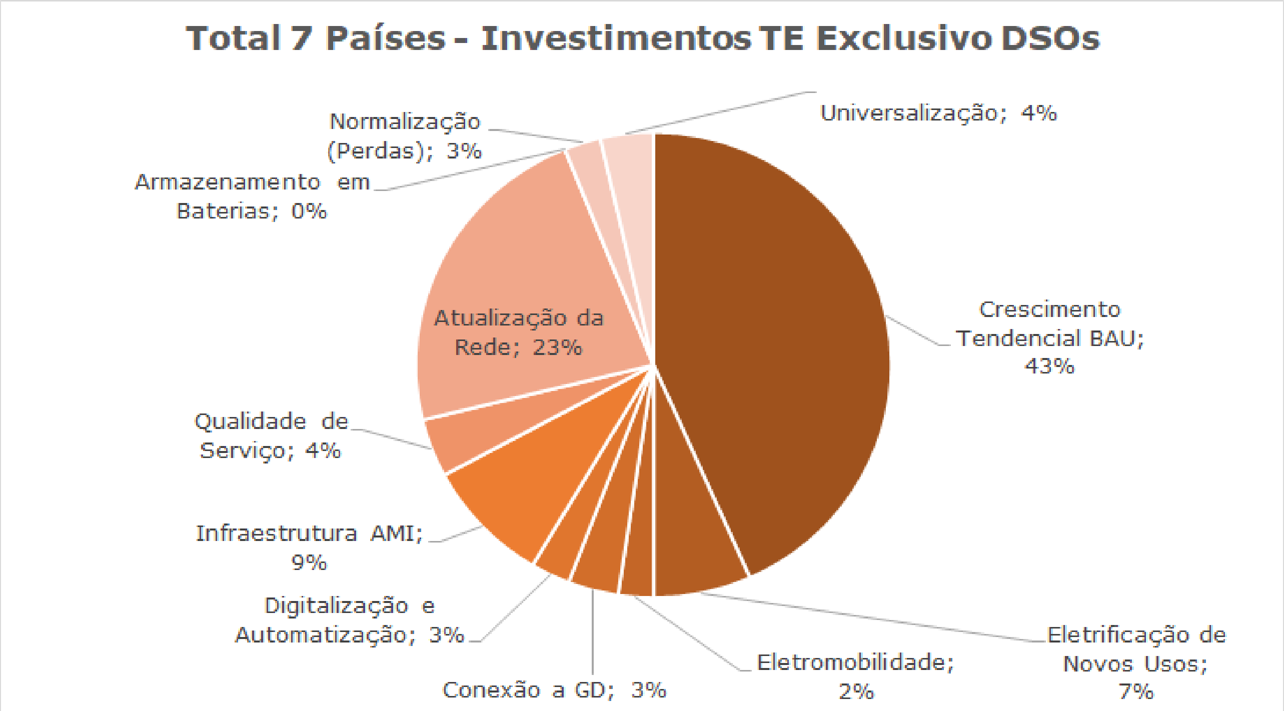
The investments in the Partial Transition scenario are distributed differently compared to the Effective Transition scenario, with a greater concentration in grid expansion under business-as-usual growth (BAU), representing 43% of the investments. The other investment vectors with the highest percentage weight in this scenario are Grid Modernization (23%), AMI Infrastructure (9%), and Electrification of New Uses (7%).

Below is a summary of the estimated average annual investments for each country in the Partial Transition scenario.

Table 5. Average Annual Investments in the Partial Transition Scenario

Partial ET Investments by 2040: 11 Vectors + BAU (USD Billions/Year)							
Item	Argentina	Brazil	Chile	Colombia	Ecuador	Guatemala	Peru
BAU	0.6	5.5	0.2	0.8	0.3	0.1	0.3
11 ET Vectors	0.8	6.6	0.4	1.2	0.4	0.3	0.5

Graph 4. Distribution of Investment Vectors in the Partial Transition Scenario



The comparison between the two scenarios shows that although both require significant investments, the Effective Transition scenario provides a greater capacity to support future demand, integrate new technologies, and improve resilience and service quality. However, this scenario also implies a greater economic effort. The Partial Transition scenario, while less ambitious, offers a more moderate alternative but could limit the potential of countries to reach network standards of developed countries. The decision on which path to follow will depend on political priorities, the availability of financing, and the implementation capacity of each country.

06

ENABLING CONDITIONS FOR INVESTMENTS

The success of the energy transition in Latin America depends not only on identifying the investment needs but also on creating a favorable environment that allows these investments to be attracted and sustained over time. In this sense, enabling conditions are fundamental to ensuring that planned investments are carried out effectively and efficiently. This chapter addresses two of the main enabling conditions: remuneration regulatory schemes and investments in other segments of the electric value chain, which are critical for developing a robust, modern distribution network ready for future challenges.

REGULATORY REMUNERATION SCHEMES

Remuneration regulatory schemes play a crucial role in attracting investments to the power distribution sector. These schemes determine how Distribution System Operators (DSOs) recover their investments and obtain a reasonable return, which in turn affects their ability to finance and execute infrastructure projects.

In a Price Cap Regulation scheme, regulators set a maximum limit for the rates DSOs can charge, incentivizing companies to improve efficiency to increase profits. This model can encourage cost containment, but if price caps are set too low, it may disincentivize the necessary investments. Additionally, DSOs are exposed to the risk that if electricity demand decreases, they cannot adjust rates to compensate for the reduction in income, which could compromise their ability to recover the investments made.

In a Revenue Cap Regulation scheme, DSOs are guaranteed a predefined level of income, so if demand decreases, rates can be adjusted upward to ensure that the projected revenue is maintained. This mitigates demand risk but introduces an efficiency risk: companies may have less incentive to make investments that improve their operational efficiency, such as those in new technologies associated with the energy transition, since their income is assured.

In a Cost Plus Regulation scheme, DSOs are compensated for their operating costs plus a guaranteed return rate on their investments. This scheme also provides limited incentive for investments in more efficient technologies, as DSOs have no motivation to reduce their costs. Additionally, there is a regulatory risk due to the dependence on the regulator's approval of costs, which limits the DSOs' flexibility.

Finally, an Incentive-Based Regulation scheme offers additional incentives for DSOs to improve service quality, operational efficiency, and technological innovation. Remuneration schemes based on incentives may include specific mechanisms to promote investment in digitalization, resilience, and loss reduction.

In the context of the energy transition, some countries have begun to develop specific regulatory schemes that offer additional incentives for investments in key areas such as the electrification of new uses, electric mobility, digitalization, and grid resilience. These schemes may include bonuses for achieving decarbonization targets, connecting distributed generation, or improving energy efficiency.

Similarly, remuneration mechanisms based on a model company that sets ex-ante remuneration based on the costs of an ideal company promote cost savings for businesses but also limit incentives for infrastructure modernization. The state-of-the-art and modern regulations show that a good remuneration scheme considers both the recognition of real costs and efficiency incentive schemes.

In Latin America, remuneration regulatory schemes face common challenges, including:

Regulatory uncertainty: Frequent changes in policies and regulatory methodologies can create uncertainty for investors, making long-term planning and access to financing difficult.

Insufficient returns: In some countries, authorized return rates may not be sufficient to cover the cost of capital, especially in economies with high macroeconomic or political risks.

Inadequate incentives for innovation: Traditional regulatory schemes may not provide the necessary incentives for DSOs to invest in emerging technologies such as digitalization or the integration of electric vehicles, which could delay grid modernization.

For remuneration regulatory schemes to serve as true enablers for energy transition investments, they need to adapt to the goals of the energy transition, incorporating clear incentives for DSOs to invest in priority areas such as grid resilience, distributed generation integration, and the electrification of new uses. Additionally, return rates must reflect the inherent risks of investments and be attractive enough to attract capital, particularly in countries with high levels of risk. Finally, regulatory frameworks must be stable and predictable, allowing DSOs and investors to plan with greater certainty and reduce the cost of financing, incorporating schemes that reward the adoption of new technologies and innovative practices that improve operational efficiency and service quality.

INVESTMENTS IN OTHER SEGMENTS OF POWER CHAIN

While this study focuses on the distribution segment, it is important to consider that the energy transition requires coordinated investment across all segments of the power value chain, including generation, transmission, and commercialization.

The transition to renewable energy sources and the electrification of new uses will increase electricity demand, which in turn will require a significant expansion of generation capacity. Investments in renewable generation and distributed generation integration are essential to decarbonize the electric supply, and these must be aligned with the distribution grid's capacity to handle the variability of renewable sources like solar and wind.

The transmission segment plays a fundamental role in connecting new renewable generation sources with consumption centers. Expanding and modernizing transmission networks and interconnections is necessary to avoid congestion and energy losses and to ensure the stability of the electric system. Additionally, integrating advanced transmission technologies, such as high-voltage direct current (HVDC) lines, can improve efficiency and transport capacity over long distances, which is particularly relevant in large territories like Brazil and Argentina. Coordination between transmission and distribution investments is crucial to avoid bottlenecks and ensure that electricity generated from renewable sources can efficiently reach end-users.

Finally, the energy transition also requires a transformation in how electricity is commercialized and how customer interactions are managed. The adoption of technologies such as advanced metering infrastructure (AMI) and the digitalization of customer relations will enable DSOs to offer more personalized and efficient services, such as demand management, dynamic billing, and the integration of electric vehicles. These investments in commercialization and customer services are necessary to fully capitalize on the benefits of digitalization and to involve consumers in the energy transition, promoting more efficient energy use and greater participation in distributed generation and storage schemes.

> The success of the energy transition in Latin America does not only depend on identifying investment needs.

07

CHARACTERIZATION OF THE BENEFITS OF ENERGY TRANSITION INVESTMENTS

Investments in energy transition in Latin America are not only necessary to meet decarbonization and modernization goals in the power sector but also generate a series of benefits that positively impact various areas. This chapter aims to qualitatively characterize the operational, economic, social, and environmental benefits that result from the implementation of investments across the different vectors of the energy transition. ADELAT will develop a second phase of the study, in which a quantitative assessment of these benefits' impact will be carried out.

OPERATIONAL BENEFITS

Investments in the energy transition have a direct impact on improving the operational efficiency of electric infrastructure, enhancing the financial sustainability of distribution system operators (DSOs). The operational benefits can be broken down into several key aspects:

Reduction in operating expenses due to fewer inspection tasks: Digitalization and automation, along with the implementation of AMI infrastructure, improvements in service quality, investments in resilience, and grid modernization, enable more efficient grid monitoring, significantly reducing the need for physical inspection tasks. This translates into lower operational costs (OPEX) for operators.

Reduction in operating expenses due to fewer interventions required from service interruptions: The same vectors mentioned above also contribute to lowering OPEX by reducing the frequency and need for grid interventions. The ability to detect and solve problems remotely and preventively, thanks to increased grid automation (self-healing), reduces interruptions and on-site interventions.

Reduction in operating and capital expenses (long-term) through optimization and increased flexibility in grid operations: Investments not only improve grid operation but also optimize the use of existing assets. This allows for greater operational flexibility, reducing both operating and capital costs in the long term.

Reduction in labor risks (associated with fewer task requirements): Automation and digitalization of operations, along with the implementation of AMI infrastructure, resilience, and grid modernization, reduce the need for manual and on-site tasks. This, in turn, lowers associated labor risks, improving the safety of the workforce.

Reduction in commercial management costs due to fewer required tasks: Digitalization and automation allow for more efficient commercial management, reducing the need for tasks such as meter reading, service disconnections and reconnections, and complaint verifications. AMI infrastructure plays a key role in this reduction by automating and optimizing processes that previously required manual intervention.

Reduction in customer service costs and increased digital interaction: Finally, the implementation of digital technologies improves the customer experience by reducing the need for physical interactions to resolve issues and manage services. This not only lowers customer service costs but also increases digital engagement, allowing operators to offer a more agile service focused on user needs.

Table 6. Operational Benefits

Operational Benefits	Electrification of New Uses	Electromobility	Connection DG	Digitalization and Automation	AMI Infrastructure	Service Quality	Resilience	Grid Modernization	Battery Storage	Loss Normalization	Universalization
Reduction of OPEX costs due to fewer inspection tasks				x	x	x	x	x		x	
Reduction of OPEX costs due to fewer intervention tasks				x	x	x	x	x			
Reduction of OPEX and CAPEX costs (long term) due to optimization and flexibility of the distributor's grid operation		x	x	x	x	x	x	x	x		
Reduction of labor risks (associated with fewer tasks)				x	x	x	x	x			
Reduction of management costs due to lower need for tasks (meter reading, disconnection, reconnection, claim verification, etc.)				x	x						
Reduction of customer service costs and increased digital interaction				x	x						

ECONOMIC BENEFITS

Investments in the energy transition not only have a positive impact on grid operations but also generate significant economic benefits for DSOs, consumers, and the industry in general. These benefits reinforce the economic viability of the energy transition and highlight its importance not only in terms of sustainability but also as an engine of economic development in the region. The main economic benefits derived from these investments are detailed below according to the different vectors of the transition.

Development of new business opportunities potentially capturable by DSOs: Electrification of new uses, electric mobility, distributed generation (DG) connection, digitalization, automation, and AMI deployment open the door to the development of new business models that can be captured by DSOs. These opportunities include demand management, electric vehicle charging services, and advanced energy efficiency solutions, among others.

Improvement in industrial competitiveness through long-term energy cost reductions: The connection of DG and battery storage allows for a long-term reduction in energy costs, improving the competitiveness of industries. By ensuring a more stable and economical electricity supply, companies can reduce their operating costs, resulting in greater capacity to compete in local and international markets.

Reduction in final energy bills for residential consumers: Improved service quality, increased resilience, and grid modernization directly translate into lower final energy bills for consumers. This is due to greater efficiency in energy use, reduced grid losses, and access to cheaper and more sustainable energy sources.

Reduction in investment needs for contingency measures: Resilience, grid modernization, service quality, and battery storage contribute to reducing the need for investment in contingency measures, such as emergency generators. Improved electric service quality reduces the frequency and duration of outages, decreasing reliance on costly alternative solutions to ensure supply continuity.

Reduction in the need for energy imports (in some countries): The incorporation of distributed energy resources also helps reduce dependence on energy imports in some countries. By increasing the efficiency and storage capacity of local energy, the need to import fossil fuels or other forms of energy is reduced, improving the trade balance and reducing exposure to international market fluctuations.

Table 7. Economic Benefits

Economic Benefits	Electrification of New Uses	Electromobility	Connection DG	Digitalization and Automation	AMI Infrastructure	Service Quality	Resilience	Grid Modernization	Battery Storage	Loss Normalization	Universalization
Development of New Business potentially capturable by DSOs	x	x	x	x	x				x		
Improved competitiveness in the industry thanks to long-term reduction of energy costs			x						x		
Reduction in the final bill paid by residential users for total energy consumption	x	x	x	x	x					x	
Reduction in the need for investment in contingency measures (e.g., generators) thanks to improved service quality						x	x	x	x		
Reduction in the need for energy imports (in some countries			x						x		

SOCIAL BENEFITS

The energy transition in the power distribution segment not only brings operational and economic improvements but also generates a positive impact on society. These social benefits manifest in various aspects, ranging from improved living conditions to promoting equity and job creation. They underscore the importance of an inclusive and people-centered energy transition, where technology and infrastructure investments play a crucial role in building more just and equitable societies. Below are the main social benefits derived from investments in the different vectors of the energy transition.

Improvement in living conditions and promotion of regional and circular economies: Access to electricity is fundamental for improving the living conditions of populations. Universalization of electricity allows more people, especially in rural and low-income areas, to access reliable energy. This not only enhances quality of life but also promotes the development of regional economies and fosters a circular economy, creating a virtuous cycle of economic and social development.

Reduction of gender gap and promotion of productive development: Electrification of new uses and universalization of services contribute to reducing the gender gap, especially in sectors where energy is a key enabler for productive activities. Improved energy efficiency in households also frees up time and resources, particularly benefiting women who traditionally take on most household tasks.

Creation of skilled jobs: Electrification of new uses, electric mobility, DG connection, and battery storage generate new opportunities for skilled and high-quality jobs. The demand for new energy technologies and services creates emerging markets that require workers with specialized skills, contributing to reduced unemployment and the development of human capital in the region.

Improvement in public safety: Resilience, grid modernization, and AMI infrastructure contribute to improved public safety. Modernizing street lighting networks and implementing more efficient and reliable systems not only reduce crime rates but also improve quality of life by providing safer and more livable environments.

Identification and targeting of vulnerable users: Digitalization and automation, along with AMI infrastructure, allow for better identification and targeting of vulnerable users who require subsidies and assistance. This facilitates a more efficient management of resources aimed at supporting the most needy populations, ensuring that subsidy policies reach those who truly need them and improving social equity.

> “Investments in the energy transition have a direct impact on improving operational efficiency.

Table 8. Social Benefits

Social Benefits	Electrification of New Uses	Electromobility	Connection to DG)	Digitalization and Automation	AMI Infrastructure	Service Quality	Resilience	Grid Modernization	Battery Storage	Loss Normalization	Universalization
Access to electricity allows for a general improvement in living conditions and the promotion of regional economies and circular economy											x
Access to electricity allows for a reduction in the gender gap thanks to improvements in household efficiency and the possibilities for productive activities	x										x
Generation of qualified and quality employment thanks to the development of new markets	x	x	x						x		
Improvement in public road safety							x	x		x	x
Mejora en la identificación y focalización de usuarios vulnerables (subsidios) y en la gestión de proximidad				x	x						

ENVIRONMENTAL BENEFITS

The energy transition also generates significant environmental benefits, manifested through reduced energy consumption and greenhouse gas (GHG) emissions. These benefits are a direct consequence of implementing more efficient technologies, integrating renewable energy sources, and optimizing the operation of the power distribution grid. Below are the main environmental benefits derived from investments in the different vectors of the energy transition.

Reduction in energy consumption and emissions through the replacement of conventional sources: Electrification of new uses, electric mobility, DG connection, and battery storage significantly contribute to reducing energy consumption and GHG emissions. This benefit is achieved by replacing conventional and less efficient energy sources with cleaner and more sustainable alternatives, such as renewable electricity. Electrification in sectors like transportation and industry enables greater energy efficiency, reducing the dependence on fossil fuels and decreasing emissions.

Reduction in emissions through the replacement of conventional generation with distributed renewable resources: DG connection enables the integration of renewable energy sources, such as solar and wind, directly into the distribution grid. The expansion of DG not only contributes to decarbonizing the energy matrix but also promotes a more efficient and sustainable use of available energy resources.

Reduction in energy consumption and emissions through grid operation optimization: Investments in digitalization and automation, along with AMI infrastructure and battery storage, optimize the operation of the distribution grid. This optimization leads to greater efficiency in power distribution, reducing technical losses and, consequently, energy consumption and associated emissions. Grid modernization through these technologies is crucial to maximizing the electric system's efficiency.

Reduction in energy consumption and emissions through loss reduction: Normalizing grid losses reduces the amount of energy that needs to be generated to meet demand, thereby decreasing GHG emissions by avoiding the waste of resources and contributing to a more sustainable grid.

Table 9. Environmental Benefits

Environmental Benefits	Electrification of New Uses	Electromobility	Connection to DG	Digitalization and Automation	AMI Infrastructure	Service Quality	Resilience	Grid Modernization	Battery Storage	Loss Normalization	Universalization
Reduction in energy consumption (and emissions) by replacing conventional sources with more efficient alternatives	X	X	X						X		
Reduction in emissions by replacing conventional generation sources with distributed renewable resources			X						X		
Reduction in energy consumption (and emissions) by improving grid operation (optimization)				X	X				X		
Reduction in energy consumption (and emissions) by reducing energy losses										X	

08

CONCLUSIONS AND RECOMMENDATIONS

The energy transition in Latin America represents a historic opportunity to transform the electric sector and advance towards a more sustainable, resilient, and inclusive future. The energy transition is not an option but an imperative need for Latin America to meet its climate commitments, ensure energy security, and promote sustainable economic development. Investments in modernizing the electric distribution network are essential to respond to demand growth, integrate renewable energy sources, improve service quality, and reduce greenhouse gas emissions.

The investment model results show that the magnitude of the investments required for an effective energy transition is significant, and countries in the region will need to mobilize considerable resources to modernize their electric infrastructures. In the Effective Transition scenario, the necessary investments are substantially higher, which highlights the importance of a strong commitment from governments, companies, and society as a whole to achieve decarbonization goals. Among the main results of the study, the following points stand out:

The investments needed for the Effective Transition scenario are estimated at USD 431 billion for the distribution segment exclusive to DSOs, a value 201% higher than the investments that would be made in the BAU growth scenario. In contrast, for the Partial Transition scenario, the investments amount to USD 307 billion, 131% higher than the BAU scenario.

Between 33% and 43% of the investments required in both scenarios correspond to BAU growth expenses, i.e., investments necessary regardless of the energy transition.

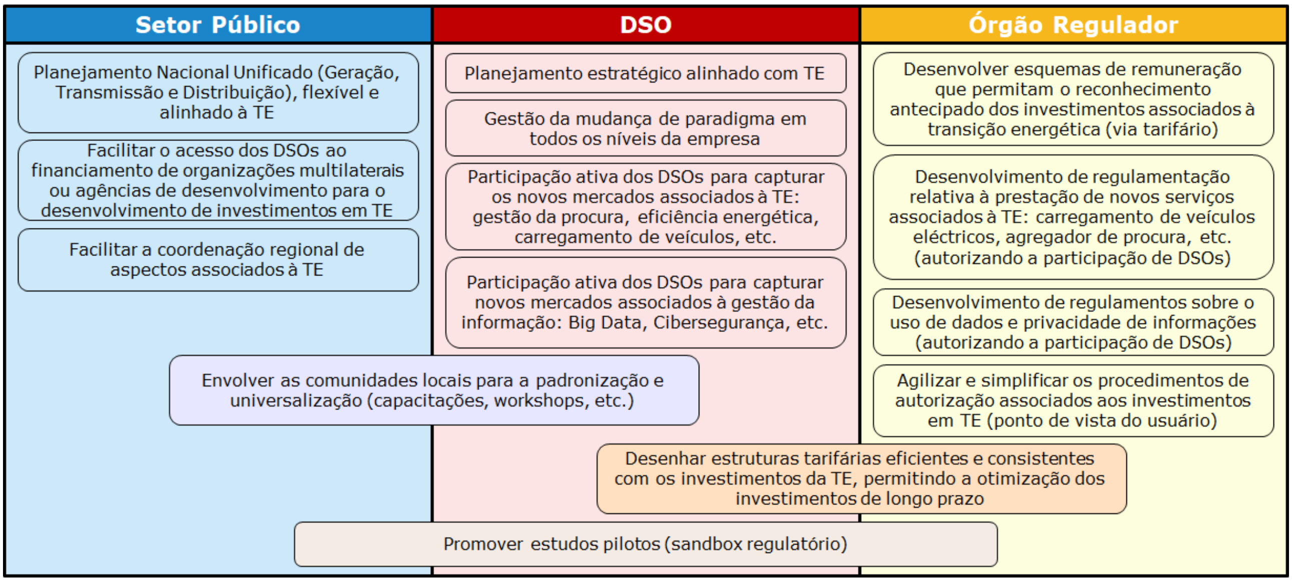
Among the eleven energy transition vectors analyzed, the ones with the greatest participation in the estimated investments are those related to grid modernization, AMI infrastructure deployment, and electrification of new uses.

The results obtained in this study are consistent with the analyses developed by Euroelectric-Deloitte for European countries, which reinforces the validity of the methodological approach used.

Investments in the energy transition generate benefits that go beyond improving the operational efficiency of the electric system. From an economic standpoint, investments can stimulate growth, create jobs, and improve the competitiveness of countries in the region. In social terms, investments can help reduce energy poverty, improve quality of life, and promote social inclusion. From an environmental perspective, transitioning to renewable energies and reducing GHG emissions are critical to mitigating the effects of climate change and conserving natural resources.

Despite the potential benefits, the energy transition faces several challenges and barriers. Among the most significant are financial constraints, regulatory uncertainty, resistance to change from some stakeholders, and the need to develop technical and operational capacities within DSOs. Overcoming these challenges will require a coordinated and strategic approach, as well as continued support from public policies that favor the transition. These could consider the recommendations summarized below.

Figure 5. Recommendations for the Public Sector, DSOs, and Regulators



RECOMMENDATIONS FOR THE PUBLIC SECTOR

Unified National Planning: It is recommended to develop a unified national energy plan that integrates policies and strategies for generation, transmission, and distribution, ensuring that all areas are aligned with the energy transition goals and that they promote synergy between different sectors, such as energy, transportation, and industry. This planning should be flexible to adapt to rapid technological innovations and changes in energy demand. Additionally, it should incorporate the participation of multiple stakeholders, including the private sector, regional and local governments, and civil society.

Access to Financing: It is essential that governments facilitate access for DSOs to international financing sources, such as multilateral banks and development agencies. This financing is crucial to carry out the necessary investments in distribution infrastructure, especially in large-scale projects like renewable energy integration and smart grid expansion. The public sector can promote favorable financial conditions, including low-interest rates and extended grace periods, allowing DSOs to make the necessary investments without jeopardizing their financial stability.

Regional Coordination: Regional coordination among countries should be encouraged to address common challenges in the energy transition. This includes harmonizing regulations and technical standards, creating integrated regional power markets, and cooperating on transnational infrastructure projects, such as electric interconnections. Regional coordination is also key to optimizing shared energy resources and ensuring energy security across the region.

RECOMMENDATIONS FOR DSOS

Strategic Planning Aligned with the Energy Transition: DSOs must continuously develop and update their strategic plans to align with the energy transition goals. This involves anticipating future investment needs, identifying new market opportunities, and adapting to changes in energy demand. Strategic planning should consider integrating emerging technologies such as smart grids, energy storage, and advanced demand management systems to ensure that distribution networks are prepared for future challenges.

Change Management: The energy transition will require a paradigm shift in how DSOs operate. It is necessary to implement change management programs that prepare all levels of the organization for the new realities of the energy sector. This includes continuous workforce training on new technologies and processes, fostering a culture of innovation and adaptability, and organizational restructuring when necessary to improve operational efficiency and responsiveness to market demands.

Participation in New Markets: DSOs must proactively position themselves to capture new markets and services associated with the energy transition. This includes energy demand management, providing charging infrastructure for electric vehicles, and participating in aggregation and demand response markets. Additionally, they should explore opportunities in areas such as cybersecurity and data management, which will become increasingly important in a digitized grid environment.

RECOMMENDATIONS FOR REGULATORY AGENCIES

Remuneration Schemes: Regulatory bodies must design remuneration schemes that allow DSOs to recover the investments made in the energy transition in advance through rates. This is essential to ensure that they have the necessary financial incentives to invest in new technologies and grid modernization. Remuneration schemes must be transparent, fair, and able to adapt to market and technology changes.

Regulation for New Services: It is essential to develop a regulatory framework that facilitates the provision of new services associated with the energy transition, such as electric vehicle charging and demand aggregation. These regulations should allow and encourage DSOs to participate in these emerging markets, ensuring that they can capture new sources of revenue and actively contribute to the sustainability of the energy system.

Data Protection: With the increasing digitalization of the electric grid, it is crucial that regulatory bodies establish clear regulations on the use of data and privacy protection. This includes authorizing DSOs to handle and use data in ways that benefit both consumers and the system as a whole while ensuring protection against the misuse of information.

Simplification of Procedures: It is recommended to streamline and simplify the authorization and permitting procedures for investments associated with the energy transition. This includes reducing bureaucracy and approval wait times to attract investments and accelerate the development of necessary infrastructure.

CROSS-CUTTING RECOMMENDATIONS

Involving Local Communities: The success of the energy transition largely depends on the support and participation of local communities. It is recommended to develop training programs and workshops aimed at communities to explain the benefits of the transition and how they can actively participate in the process. This is especially important in rural areas, where universal access to energy can significantly transform living conditions. Community participation can also facilitate the adoption of new energy technologies and practices, reducing resistance to change and increasing social acceptance of projects.

Designing Efficient Tariff Structures: It is crucial for regulatory bodies and DSOs to collaborate in designing tariff structures that reflect the real costs of energy transition investments and that incentivize efficient energy use. This involves designing rates that not only cover investment costs but also encourage consumers to adopt more energy-efficient practices and actively participate in the energy transition. Tariffs must be equitable and ensure that all users, regardless of their socioeconomic status, can benefit from technological advances and grid modernization.

Promoting Pilot Studies: Authorities, regulators, and DSOs can promote the implementation of pilot studies that allow for testing and adjusting new technologies, business models, and regulatory strategies in a controlled environment. These studies can include implementing regulatory sandboxes, allowing safe and regulated experimentation before large-scale implementation. The results of these pilots will provide valuable data that can optimize future investment decisions and policies, minimizing the risks associated with adopting new technologies.

The energy transition in Latin America is an ambitious challenge but also a unique opportunity to build a more sustainable, equitable, and prosperous future. Investments in modernizing the electric system are the cornerstone of this transformation, and their benefits extend far beyond the energy sector, positively impacting the economy, society, and the environment. The success of the energy transition in the region will depend on the ability of countries to overcome barriers and fully commit to transforming their electric systems. The decisions made in the coming years will be crucial in defining the path towards a more sustainable, resilient, and just energy future for all.

“

Energy transition scenarios consider a more ambitious evolution of the energy system.

09

INFORMATION SOURCES

The study was based on a wide variety of information sources that provide a diverse foundation for analyzing the energy transition in the electric distribution segment in Latin America. Below are the main sources consulted:

Information provided by distribution companies: Information from distribution companies was used, including spreadsheets and technical reports, which offer specific data on existing infrastructure and energy consumption.

Publications from national regulatory agencies: Documents and reports issued by regulatory agencies such as ENRE (Argentina), ANEEL (Brazil), CNE (Chile), CREG (Colombia), ARCONNR (Ecuador), CNEE (Guatemala), OSINERGMIN (Peru), among others.

Information from government agencies and ministries: Data and analyses published by various government agencies and ministries were included, providing a comprehensive view of energy policies and grid expansion plans in each country.

Associations of distributors: Reports and publications from sectoral associations such as ADEERA (Argentina) and ASOCODIS (Colombia) were consulted to obtain a sectoral perspective on indicators and trends in electric distribution in the region.

Rural electrification planning documents: These documents provided essential information on efforts to expand energy access in rural and remote areas.

Sustainability reports and annual reports: Distribution companies regularly publish sustainability reports and annual reports on their websites, which include relevant information on their operations, infrastructure investments, and environmental commitments.

Lazard Levelized Cost of Energy Analysis Report: This report was used to obtain references on levelized energy costs.

“Connecting the Dots” by Euroelectric - Deloitte: This study was a key reference for structuring the investment model used in this analysis, providing a comparative methodological framework.

Global EV World Outlook by the IEA (International Energy Agency): This report provided projections on the global adoption of electric vehicles, a critical component for understanding future demands on the distribution infrastructure.

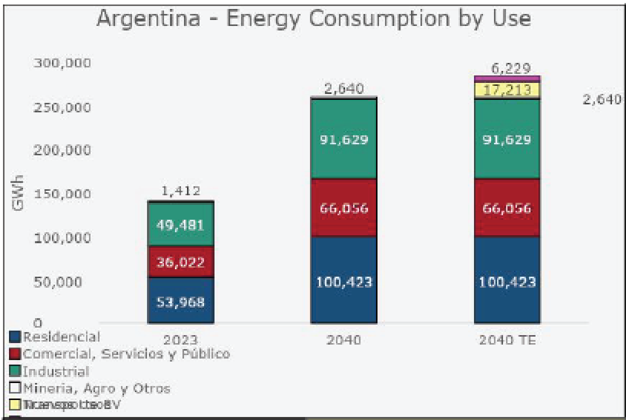
Previous studies by GME and consultations with suppliers: Data and analyses from previous studies conducted by Grupo Mercados Energéticos (GME) were incorporated, as well as additional information obtained through consultations with suppliers and other expert sources.

Demand Model Results and additional sources: For the comparative analysis, projections from Energy Transition (ET) studies by ENEL and other official bodies were considered. Additionally, information from international organizations such as ECLAC, IMF, and OLADE was integrated, providing a broader context on macroeconomic and energy trends in the region.

ANNEX: ENERGY DEMAND SCENARIOS AND RESULTS BY COUNTRY

ARGENTINA

Energy Demand Projection

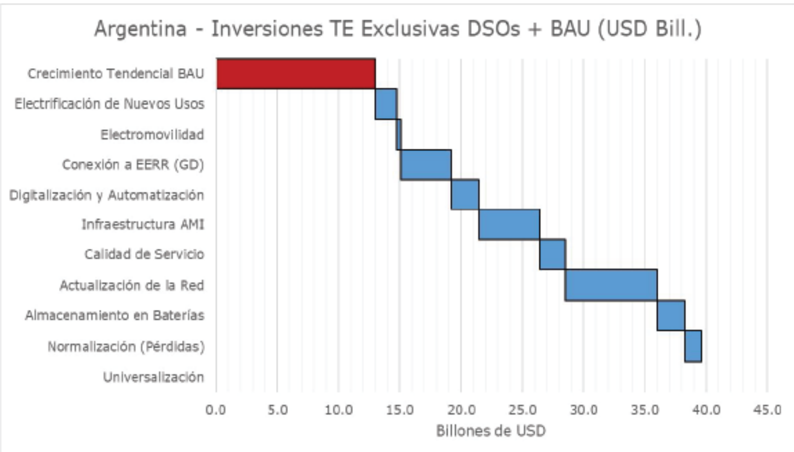


Key Aspects

- A projected energy demand of **260,748 GWh** by 2040 in the trend scenario. This demand was estimated based on econometric models (GDP and trend).
- A projected **17,213 GWh** of energy demand for new uses. This demand was estimated based on the replacement of energy consumption sources (replacement scenario GME):
  - Residential: 5,570 GWh, considering electrification replacing Biomass (50%) and LPG (50%).
  - Commercial, Services & Public: 10,430 GWh, considering 100% electrification replacing all sources.
  - Industrial: 1,213 GWh, considering electrification replacing Coal (75%), Biomass (25%), LPG (5%), Diesel (5%), and Fuel Oil (5%).
- A projected **6,229 GWh** of demand from electromobility, assuming a fleet penetration factor of 20% (TE scenario based on Euroelectric-Deloitte study).
- A projected **69,607 GWh** to be supplied by distributed generation (DG), with 15% from Prosumers and 85% from Utility Scale (TE scenario based on Euroelectric-Deloitte study).

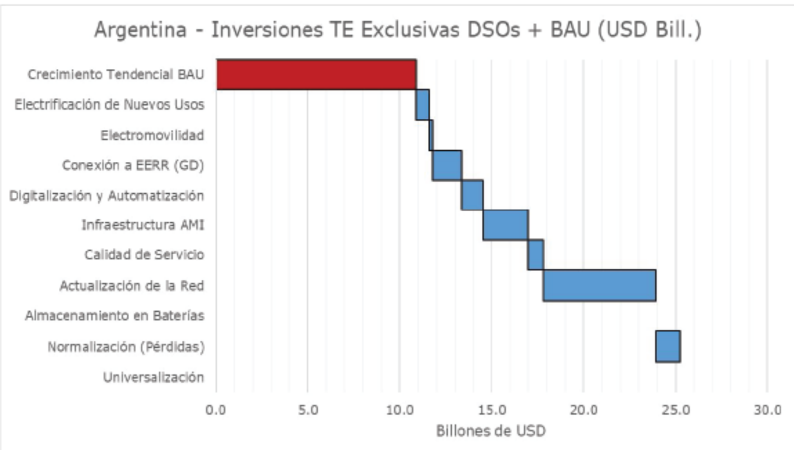
Annual Growth Rate	**Comparison**
2040 GME BAU = 3.69%	Historical (10 Years) = 1.88%
2040 GME ET = 4.21%	2050 ENEL = 4.19%

Effective Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **39.6 billion USD.**
- The annual trend growth investments amount to 0.8 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 1.6 billion USD per year..

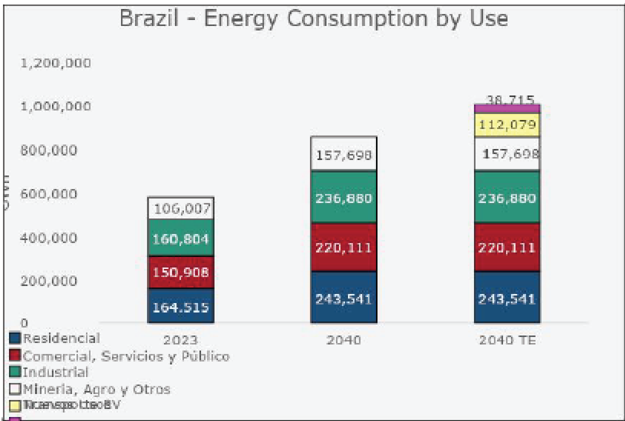
Partial Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **25.3 billion USD.**
- The annual trend growth investments amount to 0.6 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 0.8 billion USD per year.

BRAZIL

Energy Demand Projection

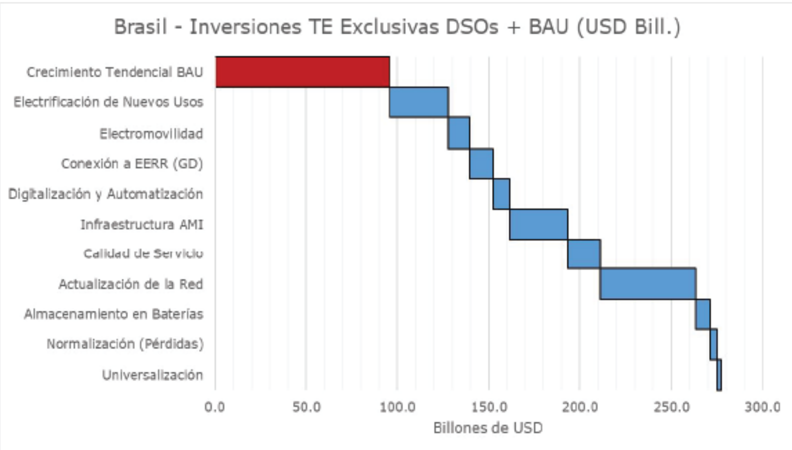


Annual Growth Rate	Comparison
2040 GME BAU = 2.31%	Historical (10 Years) = 2.22%
2040 GME ET = 3.29%	2050 ENEL = 4.26%

Key Aspects

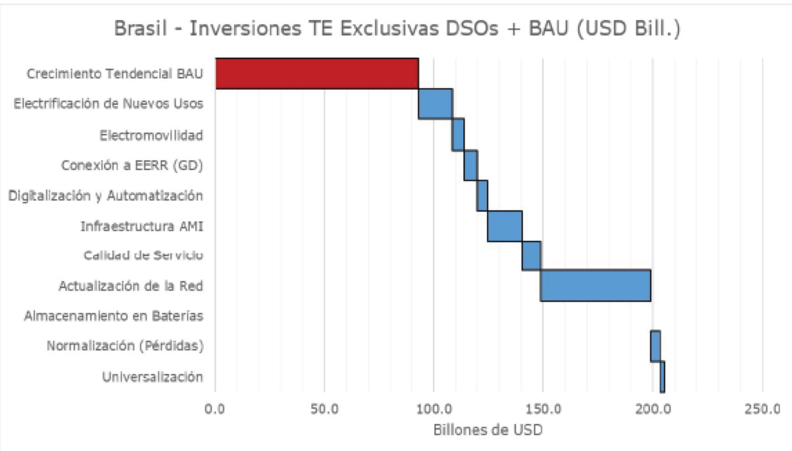
- Energy demand of **858,230 GWh** is projected for the year 2040 in the trend scenario. This demand was estimated based on econometric models (GDP and trend).
- Energy demand of **112,079 GWh** is projected for new uses. This demand was estimated based on the replacement of energy consumption sources (GME replacement scenario):
  - Residential: 48,210 GWh, considering electrification replacing Biomass (75%) and LPG (75%).
  - Commercial, Services, and Public: 6,959 GWh, considering 100% electrification replacing all other sources.
  - Industrial: 56,911 GWh, considering electrification replacing Coal (75%), Biomass (25%), LPG (5%), Diesel (5%), and Fuel Oil (5%).
- **38,715 GWh** of energy demand is projected for electromobility, consistent with a 20% penetration factor (TE assumption based on Euroelectric-Deloitte study).
- **247,143 GWh** will be supplied by distributed generation (DG), with 35% coming from Prosumers and 65% from Utility Scale (TE assumption based on Euroelectric-Deloitte study).

Effective Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **277.4 billion USD.**
- The annual trend growth investments amount to 5.6 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 10.7 billion USD per year.

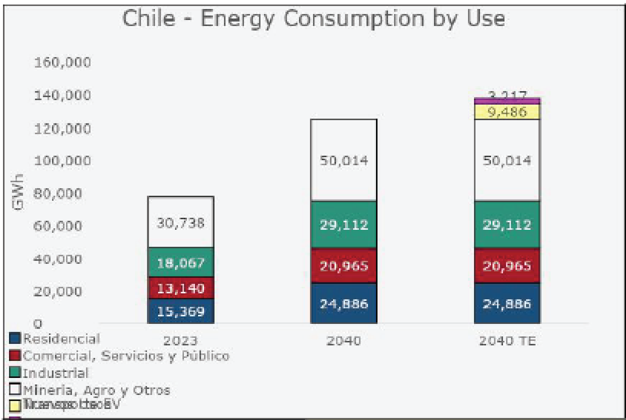
Partial Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **205.4 billion USD.**
- The annual trend growth investments amount to 5.5 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 6.6 billion USD per year.

CHILE

Energy Demand Projection

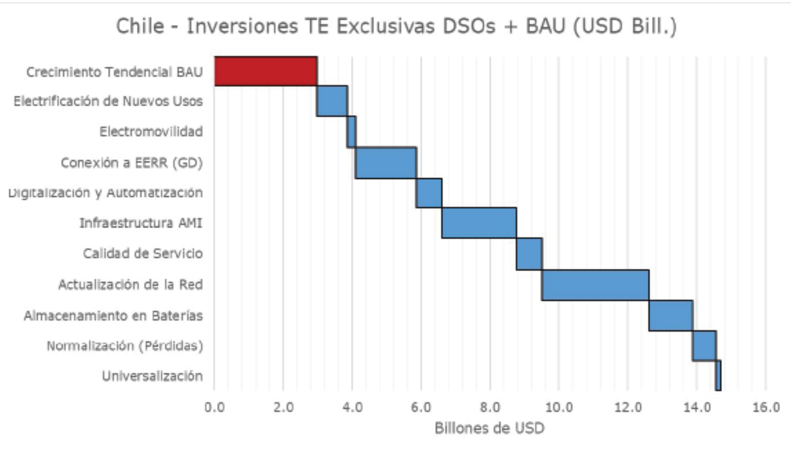


Annual Growth Rate	Comparison
2040 GME BAU = 2.87%	Historical (10 Years) = 2.69%
2040 GME ET = 3.45%	2050 ENEL = 2.66%

Key Aspects

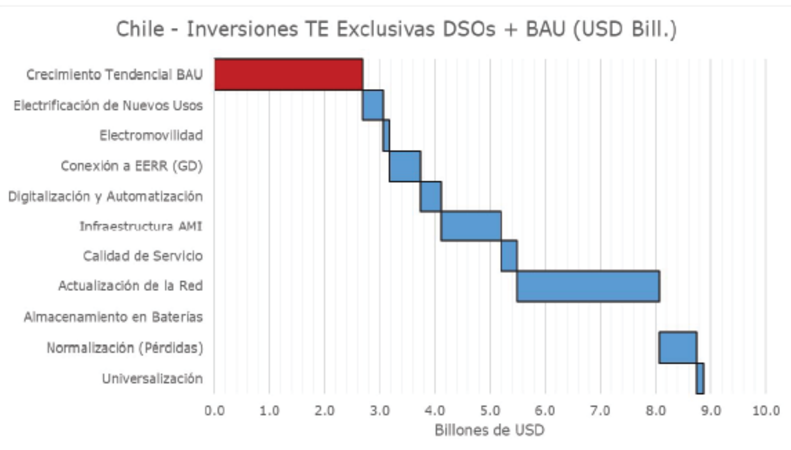
- Energy demand of **124,976 GWh** is projected for the year 2040 in the trend scenario. This demand was estimated based on econometric models (GDP and trend).
- Energy demand of **9,486 GWh** is projected for new uses. This demand was estimated based on the replacement of energy consumption sources (GME replacement scenario):
  - Residential: 7,045 GWh, considering electrification replacing Biomass (75%) and LPG (75%).
  - Commercial, Services, and Public: 227 GWh, considering 100% electrification replacing all other sources.
  - Industrial: 2,215 GWh, considering electrification replacing Coal (75%), Biomass (25%), LPG (5%), Diesel (5%), and Fuel Oil (5%).
- **3,217 GWh** of energy demand is projected for electromobility, consistent with a 20% penetration factor (ET assumption based on Euroelectric-Deloitte study).
- It is projected that **33,722 GWh** will be supplied by DG, with 15% from Prosumers and 85% from Utility Scale (ET assumption based on Euroelectric-Deloitte study).

Effective Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **14.7 billion USD.**
- The annual trend growth investments amount to 0.2 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 0.7 billion USD per year.

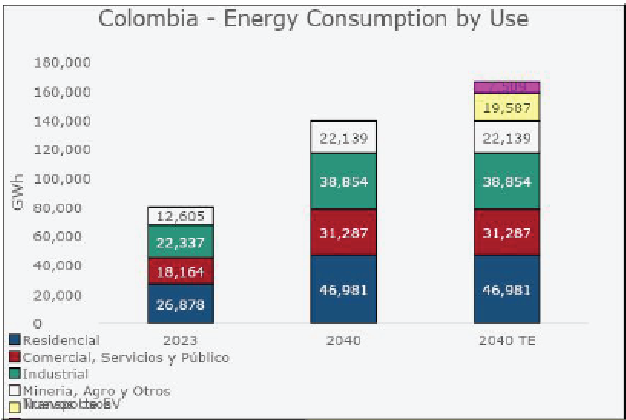
Partial Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **8.9 billion USD.**
- The annual trend growth investments amount to 0.2 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 0.4 billion USD per year.

COLOMBIA

Energy Demand Projection

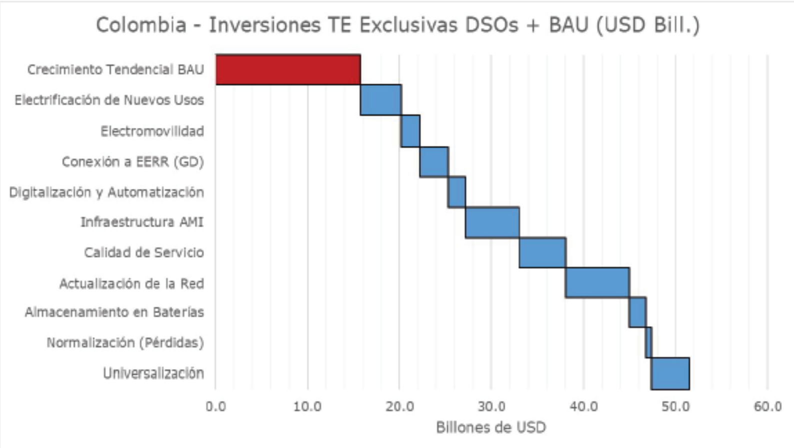


Annual Growth Rate	Comparison
2040 GME BAU = 3.32%	Historical (10 Years) = 3.63%
2040 GME ET = 4.40%	2050 ENEL = 4.54%

Key Aspects

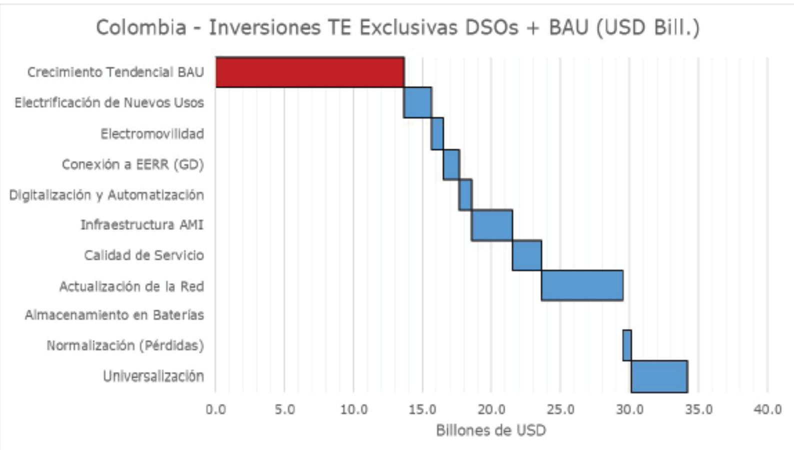
- Energy demand of **139,262 GWh** is projected for the year 2040 in the trend scenario. This demand was estimated based on econometric models (GDP and trend).
- Energy demand of **19,587 GWh** is projected for new uses. This demand was estimated based on the replacement of energy consumption sources (GME replacement scenario):
  - Residential: 4,544 GWh, considering electrification replacing Biomass (50%) and LPG (50%).
  - Commercial, Services, and Public: 4,138 GWh, considering 100% electrification replacing all other sources.
  - Industrial: 10,906 GWh, considering electrification replacing Coal (75%), Biomass (25%), LPG (5%), Diesel (5%), and Fuel Oil (5%).
- **7,509 GWh** of energy demand is projected for electromobility, consistent with a 20% penetration factor (ET assumption based on Euroelectric-Deloitte study).
- **40,746 GWh** will be supplied by distributed generation (DG), with 15% coming from Prosumers and 85% from Utility Scale (ET assumption based on Euroelectric-Deloitte study).

Effective Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **51.5 billion USD.**
- The annual trend growth investments amount to 0.9 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 2.1 billion USD per year.

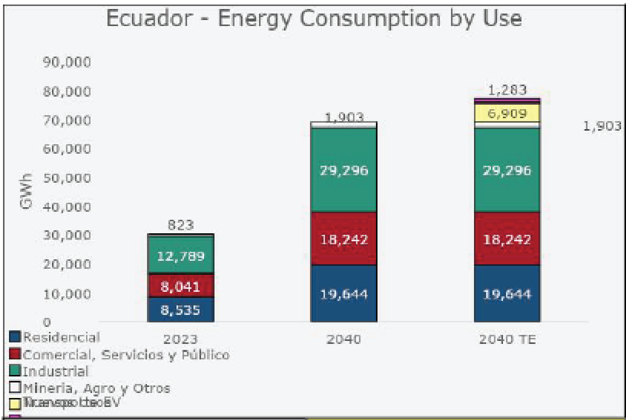
Partial Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **34.2 billion USD.**
- The annual trend growth investments amount to 0.8 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 1.2 billion USD per year.

ECUADOR

Energy Demand Projection

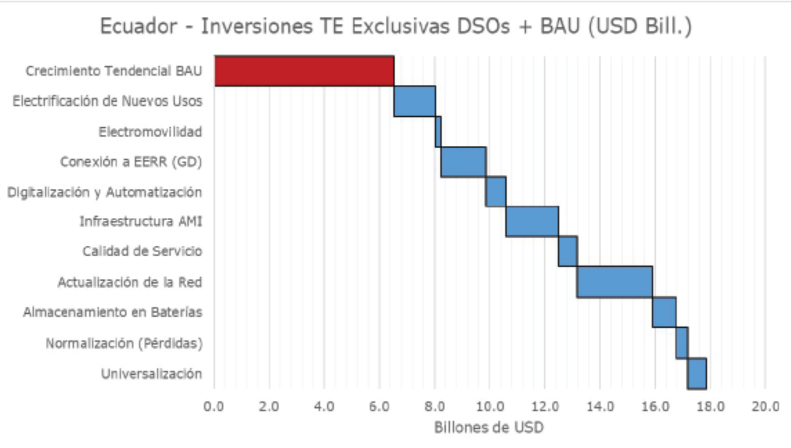


Key Aspects

- Energy demand of **69,085 GWh** is projected for the year 2040 in the trend scenario. This demand was estimated based on econometric models (GDP and trend).
- Energy demand of **6,909 GWh** is projected for new uses. This demand was estimated based on the replacement of energy consumption sources (GME replacement scenario):
  - Residential: 5,809 GWh, considering electrification replacing Biomass (75%) and LPG (75%).
  - Commercial, Services, and Public: 474 GWh, considering 100% electrification replacing all other sources.
  - Industrial: 626 GWh, considering electrification replacing Coal (75%), Biomass (25%), LPG (5%), Diesel (5%), and Fuel Oil (5%).
- **1,283 GWh** of energy demand is projected for electromobility, consistent with a 20% penetration factor (ET assumption based on Euroelectric-Deloitte study).
- **18,928 GWh** will be supplied by distributed generation (DG), with 15% coming from Prosumers and 85% from Utility Scale (ET assumption based on Euroelectric-Deloitte study).

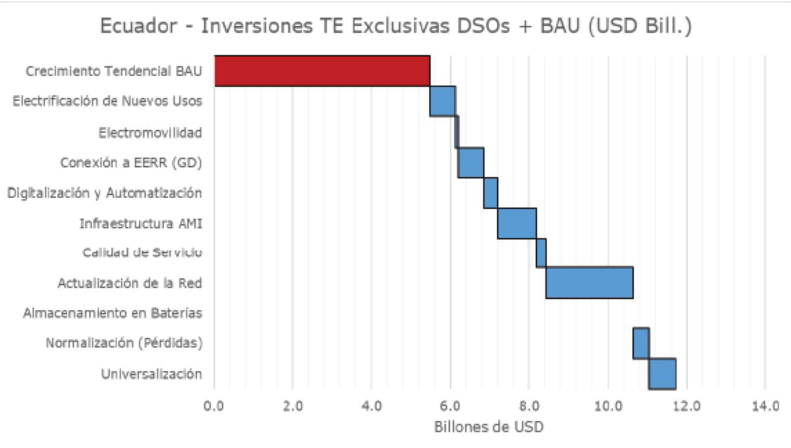
Annual Growth Rate	**Comparison**
2040 GME BAU = 4.99%	Historical (10 Years) = 4.86%
2040 GME ET = 5.68%	

Effective Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **17.9 billion USD.**
- The annual trend growth investments amount to 0.4 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 0.7 billion USD per year.

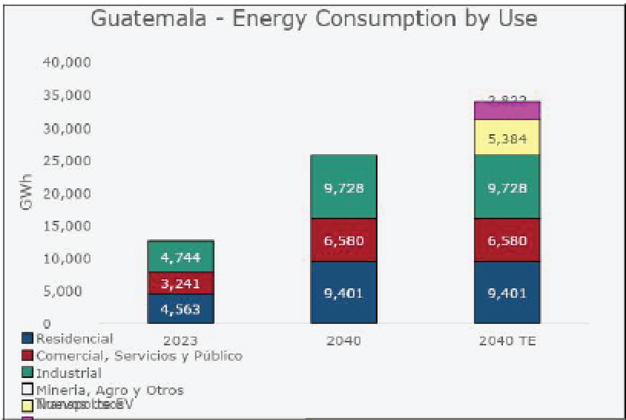
Partial Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **11.7 billion USD.**
- The annual trend growth investments amount to 0.3 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 0.4 billion USD per year.

GUATEMALA

Energy Demand Projection

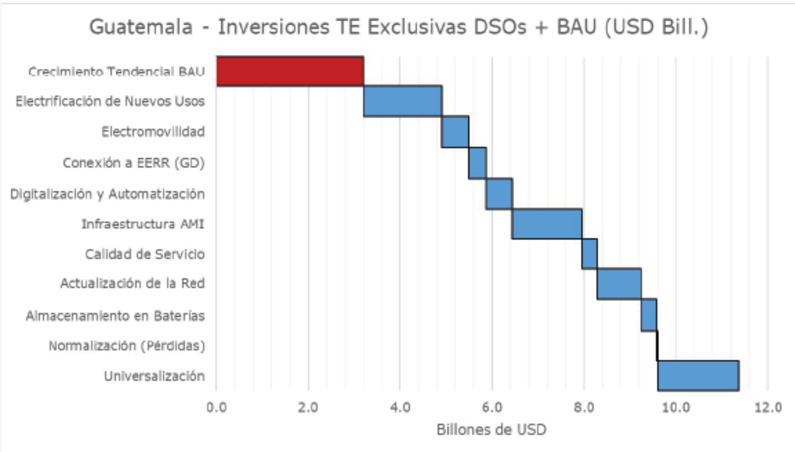


Annual Growth Rate	Comparison
2040 GME BAU = 4.31%	Historical (10 Years) = 3.99%
2040 GME ET = 6.02%	2050 ENEL = 6.00%

Key Aspects

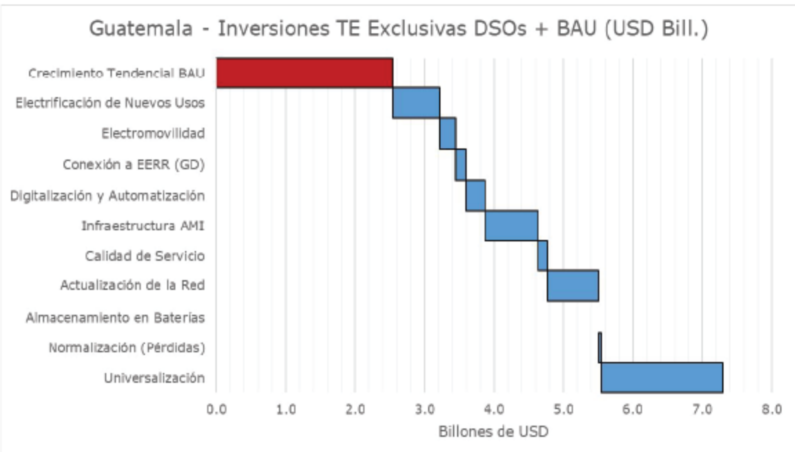
- Energy demand of **25,708 GWh** is projected for the year 2040 in the trend scenario. This demand was estimated based on econometric models (GDP and trend).
- Energy demand of **5,384 GWh** is projected for new uses. This demand was estimated based on the replacement of energy consumption sources (GME replacement scenario):
  - Residential: 4,671 GWh, considering electrification replacing Biomass (25%) and LPG (25%).
  - Commercial, Services, and Public: 557 GWh, considering 100% electrification replacing all other sources.
  - Industrial: 156 GWh, considering electrification replacing Coal (75%), Biomass (25%), LPG (5%), Diesel (5%), and Fuel Oil (5%).
- **2,822 GWh** of energy demand is projected for electromobility, consistent with a 20% penetration factor (ET assumption based on Euroelectric-Deloitte study).
- **6,285 GWh** will be supplied by distributed generation (DG), with 15% coming from Prosumers and 85% from Utility Scale (ET assumption based on Euroelectric-Deloitte study).

Effective Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **11.4 billion USD.**
- The annual trend growth investments amount to 0.2 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 0.5 billion USD per year.

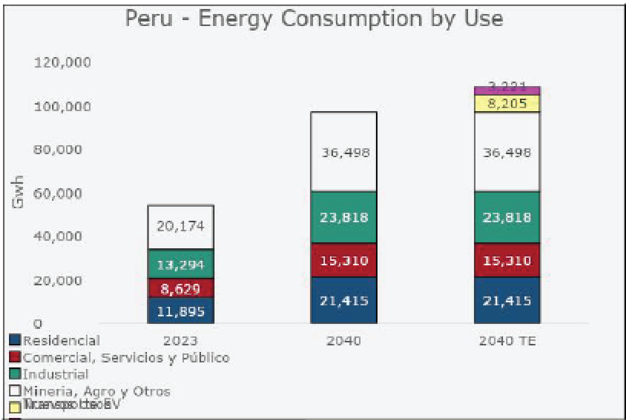
Partial Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **7.3 billion USD.**
- The annual trend growth investments amount to 0.1 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 0.3 billion USD per year.

PERU

Energy Demand Projection

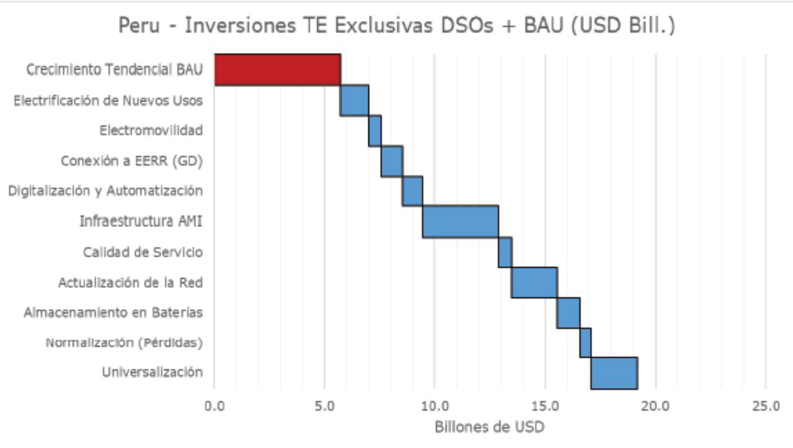


Annual Growth Rate	Comparison
2040 GME BAU = 3.51%	Historical (10 Years) = 4.21%
2040 GME ET = 4.19%	2050 ENEL = 3.88%

Key Aspects

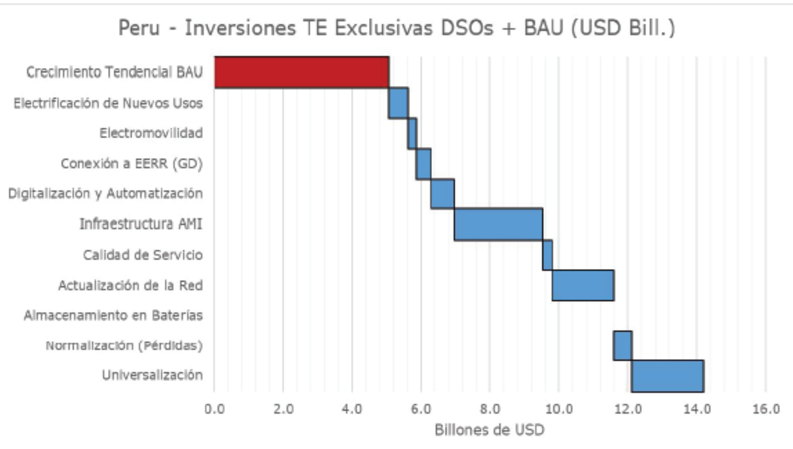
- Energy demand of **97,041 GWh** is projected for the year 2040 in the trend scenario. This demand was estimated based on econometric models (GDP and trend).
- Energy demand of **8,205 GWh** is projected for new uses. This demand was estimated based on the replacement of energy consumption sources (GME replacement scenario):
  - Residential: 2,801 GWh, considering electrification replacing Biomass (25%) and LPG (25%).
  - Commercial, Services, and Public: 2,420 GWh, considering 100% electrification replacing all other sources.
  - Industrial: 2,984 GWh, considering electrification replacing Coal (75%), Biomass (25%), LPG (5%), Diesel (5%), and Fuel Oil (5%).
- **3,221 GWh** of energy demand is projected for electromobility, consistent with a 20% penetration factor (ET assumption based on Euroelectric-Deloitte study).
- **26,567 GWh** will be supplied by distributed generation (DG), with 15% coming from Prosumers and 85% from Utility Scale (ET assumption based on Euroelectric-Deloitte study).

Effective Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **19.2 billion USD.**
- The annual trend growth investments amount to 0.3 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 0.8 billion USD per year.

Partial Transition Scenario Result



- If investments that will not necessarily be made by DSOs are excluded, the amount of investments for the ET scenario **by 2040** is reduced to **14.2 billion USD.**
- The annual trend growth investments amount to 0.3 billion USD per year.
- The annual ET investments exclusive to DSOs amount to 0.5 billion USD per year.

adelat